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AMERICAN MUSEUM OF NATURAL HISTORY

A BRIEF HISTORY OF ANTARCTIC EXPLORATION

GUIDE LEAFLET No. 31

MARCH, 1910

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A Brief History of Antarctic Exploration

A Guide Leaflet explanatory of the

Spherical Chart of the Antarctic Regions

exhibited in the

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A BRIEF HISTORY OF ANTARCTIC EXPLORATION

INTRODUCTION

The chart (which is a section of the Globe) is designed to illustrate our present knowledge of the geography of the Antarctic regions, and to indicate the courses taken by the principal Antarctic explorers.

The visitor is supposed to be looking down upon the South Pole, and therefore the area of his horizon extends in all directions toward the north, reaching beyond the Antarctic Circle [66° 30′ south, drawn in red] to the parallel of 60° south. It is a relatively small portion of the earth's surface, as will be seen by examining the small globe.

Since a degree of latitude measures about 70 miles,[1] the concentric circles representing parallels (which are 5° apart) are about 350 miles from one to another.

It is about 2,100 miles from the margin of the chart to the center, or from the parallel of 60° to the South Pole.

Meridians, drawn every 10° apart, intersect at the Pole. The meridian of Greenwich, indicated by three parallel lines, lies vertically.

The degrees of longitude are indicated along the margin, and the degrees of latitude are indicated by numerals placed on the respective parallels.

More readily to understand the historical description, it will be worth while for the visitor to remember

[1] Throughout this Leaflet distances are expressed in "statute" miles, a statute mile being about six-sevenths as long as a geographical or nautical mile.

That were the "meridian of Greenwich" continued northward, it would finally pass through Greenwich, England;

That all points lying to the right of this line are in east longitude;

That those lying to the left are in west longitude;

That were the meridian of 74° west (on the left, represented in red) extended to the north, it would pass through New York;

That the southerly projection of South America lies on the meridian of 70° west, to the left of the chart, about 600 miles from the South Shetlands;

That the southern projection of Africa lies on the meridian of 20° east, above the chart, more than 2,000 miles from the Antarctic ice.

That New Zealand lies on the meridian of 170° east, below the region included in the chart, about 1,700 miles from Victoria Land;

That between these points lie the vast expanses of the South Atlantic, South Indian and South Pacific Oceans, respectively.

The visitor, then, having established his "points of compass," may now with greater profit consult the historical labels which are attached to the rail, in the order of the dates of discovery.

JAMES COOK, 1772-75

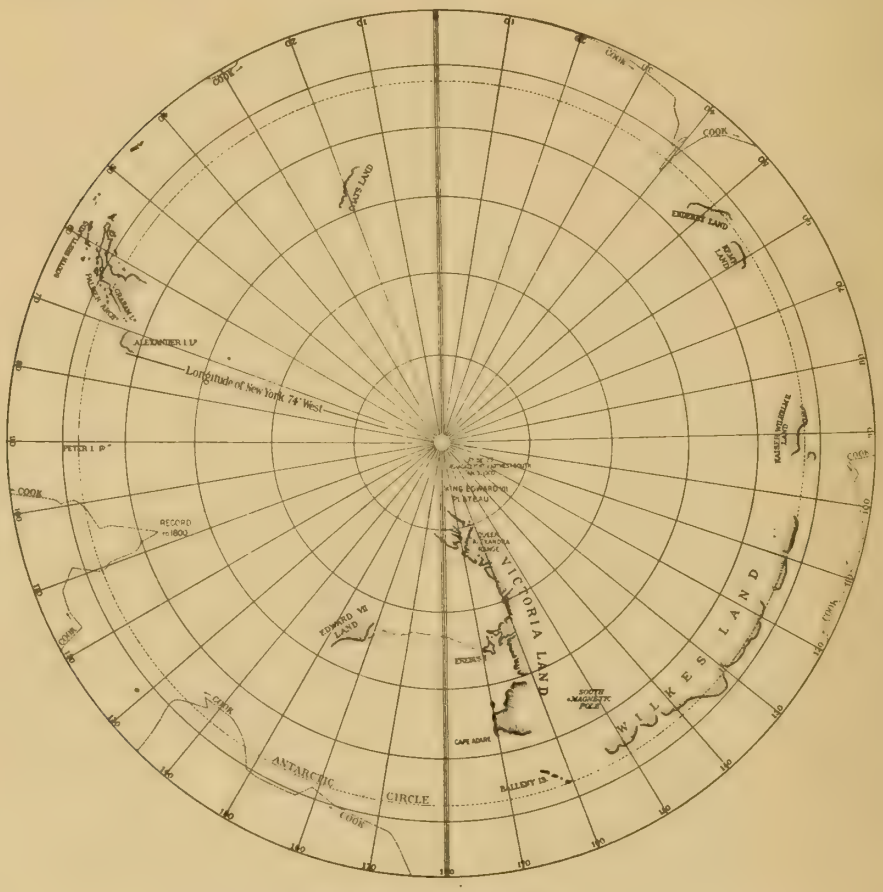
Resolution and *Adventure*

[The course is indicated on the chart by a white line.]

There was little definite knowledge of lands lying in the far south until Captain Cook, a young man of the British Navy (who, by the way, had gained distinction in North America at the siege of Quebec), sailed to the South Pacific (1768–1771) to observe the transit of Venus, and in doing so passed south of New Zealand and thus corrected the belief that this island was a part of an extensive Antarctic continent.

Later, in 1772, Cook was commissioned by the British Admiralty to command two vessels and to examine into the question of the existence of a great southern continent. He sailed from Plymouth in July, reached Cape Town in October, and entered the area of this chart near the 20th meridian of east longitude. He took an easterly course, then one abruptly south, and, on January 17, 1773, was the first person to cross the Antarctic Circle. Further progress being blocked by the ice, Cook took a northerly course. He missed the Crozet and Kerguelen islands (which lie without the area of the present map, but may be noted on the small globe). He then turned to the south, and crossed the 60th parallel near the 90th meridian, the ice

preventing him from seeing the land, which has lately been discovered and named in honor of the German Emperor, Kaiser Wilhelm II. He then continued, sometimes north and sometimes south of the 60th parallel, to about 150° E., when cold weather drove him north, where he wintered.



ANTARCTIC REGIONS

ROUTE FOLLOWED BY JAMES COOK, 1772–1775

He then returned, crossed the 60th parallel near 180° and entered the area of the chart, crossed the Antarctic Circle a second time near 150° W., turned and made a wide detour to the north, and proved that there could be no

considerable land between New Zealand and Cape Horn. He again entered the area here represented at about 120° W., crossed the Antarctic Circle for the third time, in January, 1774, near 110° W., and made his farthest south (71° 10′), a record that was not broken for half a century. It was here that he saw the solid ice like a ridge of mountains. Cook then sailed north in search of alleged land (Juan Fernandez), which he proved not to exist, and the tired party then spent the winter in the South Pacific.

On the return of the Antarctic spring, November, 1774, Cook left New Zealand and renewed his efforts. He took an easterly course near the 55th parallel until he reached the islands of Tierra del Fuego. He then rounded Cape Horn and, having proved the non-existence of a continent in the South Pacific, began his search for the "Continent of the South Atlantic"—if such should exist. He discovered South Georgia, near the 40th meridian of west longitude, but not sufficiently south to be shown on this chart. This was the first typical Antarctic land that he had found. He then barely crossed the 60th parallel, discovered the Sandwich group (examine smaller globe), which, surrounded by fields of ice, he felt might be a part of the "Southern Land." Cook then left the area of this map, sailed northeasterly, shaping his course for Cape Town, and thence to England, where he ended his extraordinary voyage. It is noteworthy that Cook, the first successful Antarctic explorer, not only circumnavigated the Antarctic regions, but proved the non-existence of any extensive Antarctic land mass extending north of the Antarctic Circle.

1775-1819

From the time of Cook's voyage, 1775, this region remained unexplored and practically unvisited for a period of more than forty years, although it is true that at the

beginning of the nineteenth century several American vessels regularly visited the shores of South Georgia and the neighboring islands off the coast of South America for seals. The more enterprising of these doubtless discovered many Antarctic islands that they never took the pains to chart or even to report upon.

WILLIAM SMITH, 1819

Williams

[The course is not indicated.]

In 1819, Captain William Smith, while sailing a British merchantman, reported the discovery of the South Shetlands (see meridian 60° W.) and sailed along their coast for a distance of 250 miles.

N. B. PALMER, 1821

Hero

[The course is not indicated.]

In 1821, an American sealer, Captain Palmer, sailed south from the Shetlands, discovering volcanic islands which have been named the Palmer Archipelago.

Captain George Powell, a British sealer, accompanied Palmer, and discovered and charted, in 1821 and 1822, the South Orkney Islands (40°–50° W.).

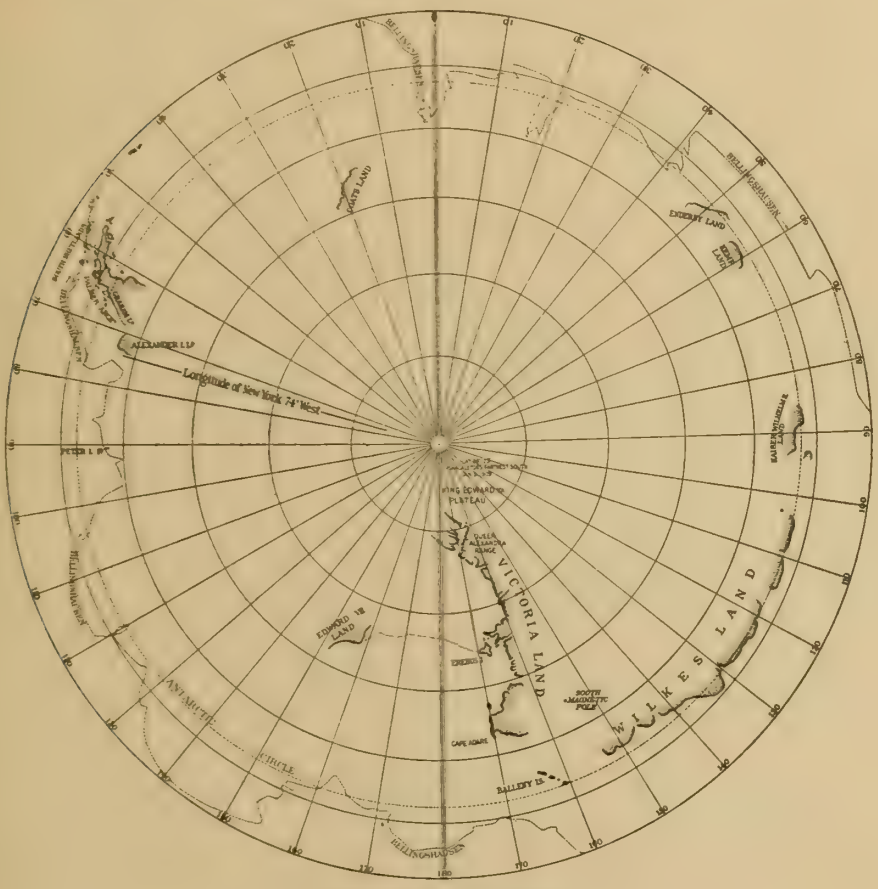
F. G. BELLINGSHAUSEN, 1820-1821

Vostok and *Mirny*

[The course is indicated by an orange line.]

After the British expedition of Captain Cook, the first really important expedition to the South Polar regions was under the patronage of the Russian Emperor, Alexander II,

who appointed Bellingshausen to the command. With two vessels Bellingshausen sailed to the south in January, 1820, near the islands of the Sandwich group (discovered by Captain Cook), then easterly, and entered the area of this chart near the meridian of 10° W.



ANTARCTIC REGIONS

ROUTE FOLLOWED BY F. G. BELLINGSHAUSEN, 1820–1821

Bellingshausen turned abruptly south, crossed the Antarctic Circle, entered an absolutely unexplored sea, and stopped only when he met the impenetrable ice of the 70th parallel. He then continued toward the east, and, follow-

ing the edge of the ice, crossed the Antarctic Circle a second time, reaching 69° S., near the meridian of 20° E., in February, 1820. He then retreated, proceeded farther eastward, and crossed the Antarctic Circle a third time, near the spot where Cook made his first crossing.

Bellingshausen then proceeded easterly near the 60th parallel, leaving the area of this map, near the meridian of 90° E., and shaped his course for Sydney, Australia.

In November, 1820, Bellingshausen again sailed to the south, crossed the 60th parallel near the 160th meridian, met the pack ice at the 65th parallel, crossed the Antarctic Circle for the fourth time (164° W.), and was obliged then to take a course north of Cook's. He crossed the Circle the fifth time on the 120th meridian west. The ice drove him temporarily to the north, but he returned, and for the sixth time crossed the Circle, at 100° W., and continuing reached his farthest south—69° 52′. Near this point he discovered Peter Island, the most southerly land then known. Still farther to the east, he discovered Alexander Island, when he was again forced by the ice to retreat, and, entering the South Shetland group, met there, February 4, 1821, among others, Captain Palmer, already mentioned. Thus ended one of the most successful and important of Antarctic expeditions.

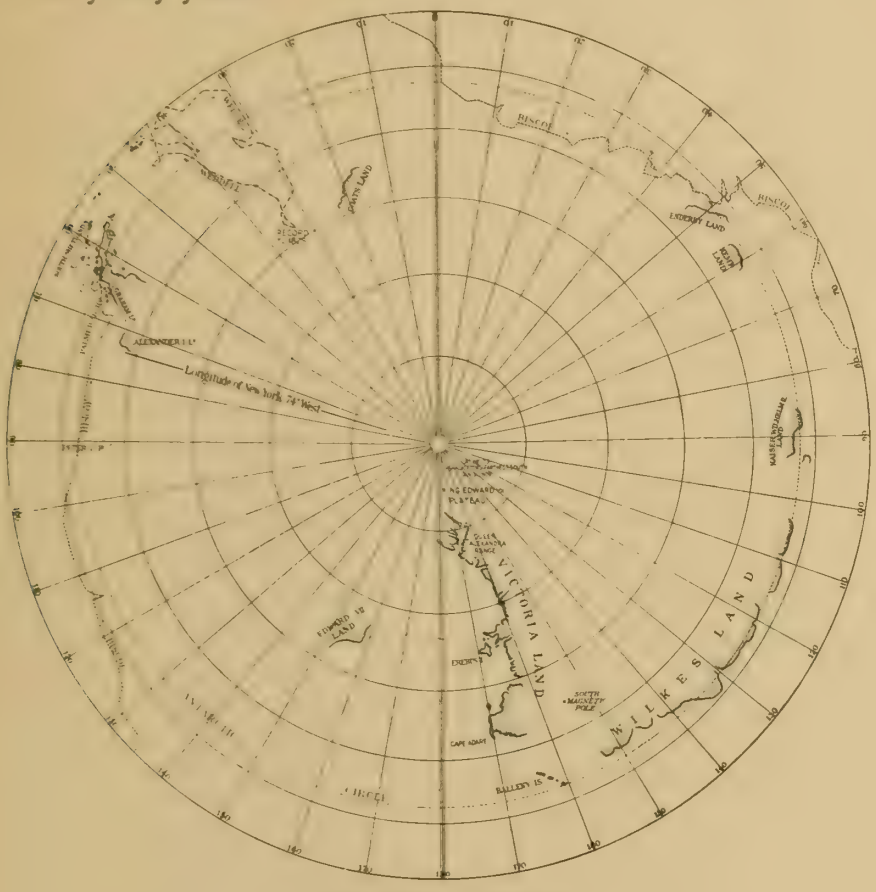
JAMES WEDDELL, 1823

Jane and *Beanjoy*

[The course is indicated by a pink line.]

In 1823, James Weddell, a brave Englishman, after having explored the South Shetlands and worked around the South Orkneys, forced two small sealing vessels southward through the sea which bears his name, to 74° 15′ S., a point 214 nautical miles nearer the pole than had been

reached by Cook, thus breaking a record that had stood nearly fifty years.



ANTARCTIC REGIONS

ROUTES FOLLOWED BY JAMES WEDDELL, 1823; JOHN BISCOE, 1830–1832

JOHN BISCOE, 1830-1832

Tula and *Lively*

[The course is indicated by a blue line.]

Enderby Land, lying at the intersection of the meridian of 50° E. and the Antarctic Circle, was discovered in 1831 by Biscoe, a British sealer exploring under a commission

from the merchant firm of Messrs. Enderby, who had entered the South Polar regions by way of the Sandwich group.

The course of Biscoe will be found entering the present map near the meridian of Greenwich; thence passing to the south, across the course taken by Bellingshausen, eleven years earlier, to the point on the 40th meridian east reached by Cook and Bellingshausen, thence along the Antarctic Circle to Enderby Land.

Severe sickness and other trials now compelled Biscoe to turn north, and he left the area of this map near the 80th meridian. He wintered in Tasmania. With the return of warm weather, he sailed from Tasmania east, crossed the 60th parallel near 140° W., followed near the course of Bellingshausen, crossed the Antarctic Circle near the meridian of 80° W. and entered Bellingshausen Sea, where he discovered land, now known as the Biscoe Islands.

Biscoe, unacquainted with the earlier work of the Russians, supposed that he had discovered land lying farther to the south than that found by any other explorer. He landed on the Palmer Archipelago and described new land which, in honor of Lord Graham, he called "Graham Land." He then returned home.

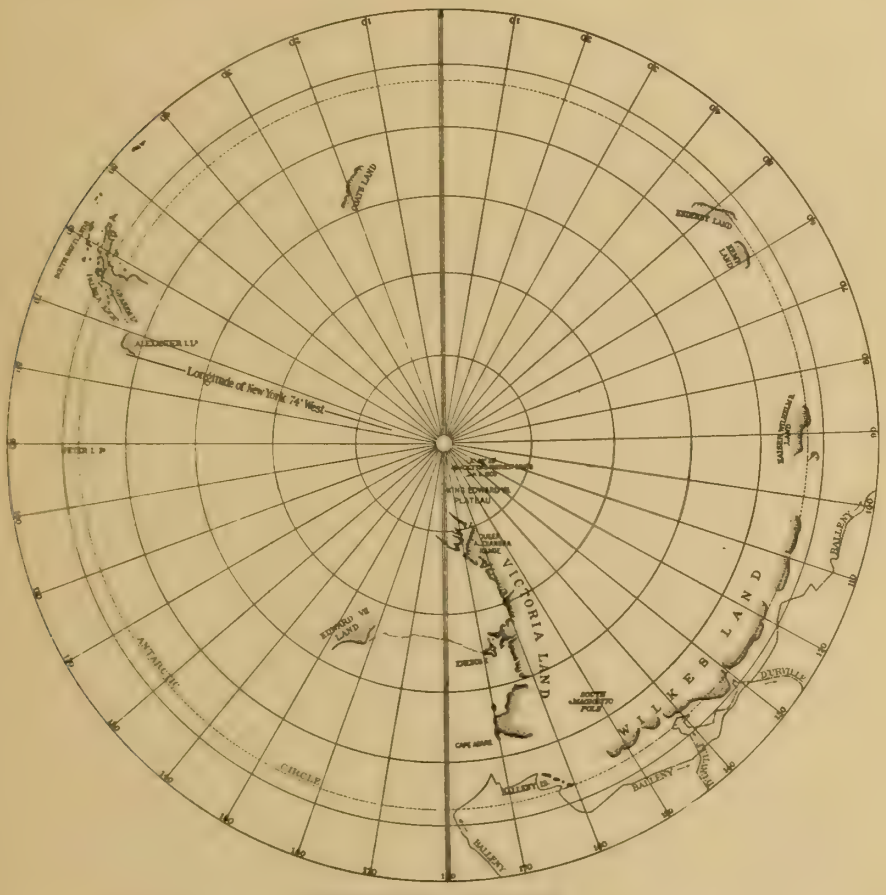
DUMONT D'URVILLE, 1837-1840

Astrolabe and *Zelée*

[The course is indicated by a green line.]

In September, 1837, the French sent Commander d'Urville, in charge of two warships, to explore in the south. He attempted to enter Weddell Sea, but ice prevented. He then sailed to the westward and early in 1838 explored the land to the south of the South Shetlands, dedicating it to his sovereign, Louis Philippe. He then

entered the Pacific, where he remained for two years. Leaving Tasmania and again entering the southern seas, d'Urville found land, stretching indefinitely to the east and west, in the latitude of the Antarctic Circle and near the meridian of 140° E. Landing parties found the rocks to be of granite.



ANTARCTIC REGIONS

ROUTES FOLLOWED BY DUMONT D'URVILLE, 1837–1840; JOHN BALLENY, 1838–1839

While in this neighborhood, d'Urville unexpectedly met an American expedition under Wilkes.

With the return of d'Urville, French activity in the Antarctic was brought to a close, until its recent revival.

JOHN BALLENY, 1838-1839

Eliza Scott and *Sabrina*

[The course is indicated by a brown line.]

In 1838, the Enderbys (who, as before stated, had made it possible for Biscoe to circumnavigate the Antarctic), in conjunction with other London merchants, sent two vessels under John Balleny into the Antarctic, with instructions to push as far to the south as possible. Balleny entered from New Zealand, near the meridian of 180° and crossed Bellingshausen's track. Entering what was later known as Ross Sea, he discovered in 1839 the group of small volcanic islands which bears his name. This was the first land found within the Antarctic Circle south of New Zealand, and its discovery was the first step toward the final discovery of Victoria Land. Balleny left the area of this map at 100° E., failing, however, to discover the land which we now know was just south of his course. Members of this expedition, on returning, reached London in time to meet Ross before the departure of the *Erebus* and *Terror*.

CHARLES WILKES, 1839-1840

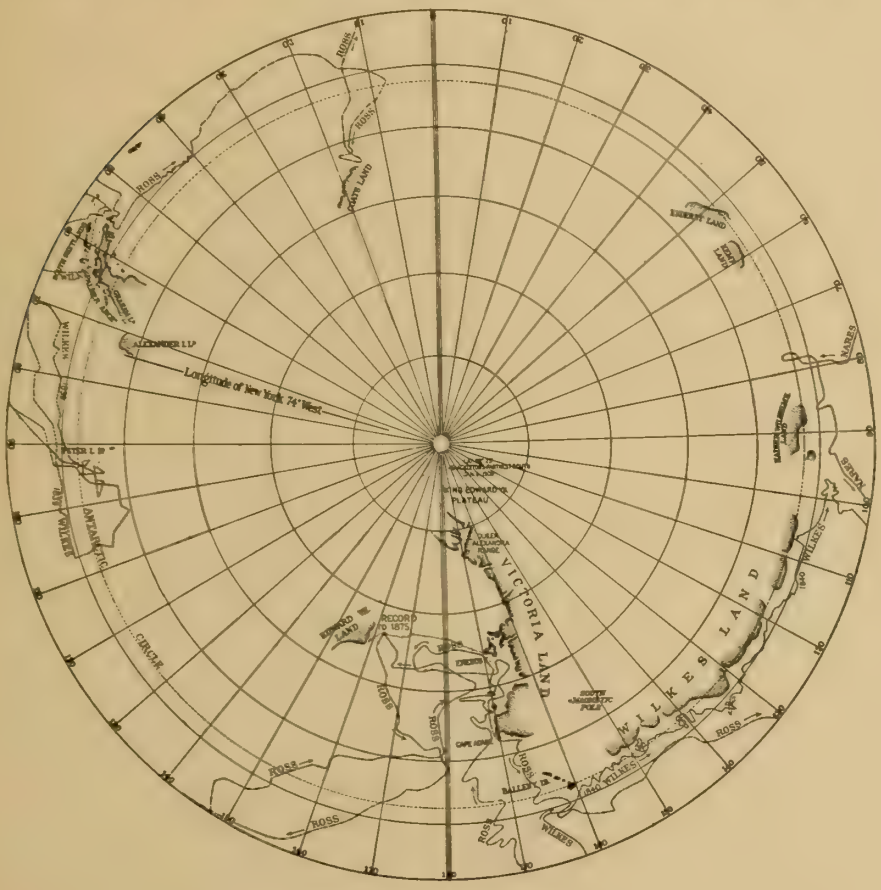
Vincennes, *Peacock* and *Porpoise*

[The course is indicated by a red line.]

In February, 1839, Lieutenant Charles Wilkes, at the head of the United States Exploring Expedition, with a squadron of six vessels poorly equipped and poorly adapted to polar work, entered the South Polar regions from Tierra del Fuego.

He first made an effort to explore land to the south of the South Shetlands, in the neighborhood of 60° W., and then in the neighborhood of Cook's farthest south, 105° W. These efforts were unsuccessful. Four of the vessels then proceeded to Sydney, Australia, whence two under

Wilkes and two under Ringgold roughly explored the strip of land, or lands, lying near and parallel to the Antarctic Circle, which extends from the Balleny Islands (165° E.) to 95° E., a distance of 1500 miles, a tract now known in



ANTARCTIC REGIONS

ROUTES FOLLOWED BY CHARLES WILKES, 1839–1840; JAMES CLARK ROSS, 1839–1843; G. S. NARES, 1874

general as Wilkes Land. He thus took a course in this area more southern than that of any previous explorer known to him, although d'Urville, in a quick sail to the south from Tasmania, had discovered Adélie Land on the

140th meridian at about the same time. The American and French expeditions met each other near this point. The course of Wilkes, as he returned from the Antarctic, will be found to cross the 60th parallel near the meridian of 100° E.

JAMES CLARK ROSS, 1839-1843

Erebus and *Terror*

[The course is indicated by a purple line.]

James Clark Ross, a nephew of Sir John Ross, the Arctic explorer, and one who had had several years of Arctic experience (indeed it was he who in 1831 had sledged to the North Magnetic Pole and planted there the British flag), left Tasmania in 1840 in command of the *Erebus* and *Terror*. The primary object of the expedition was to make certain magnetic explorations in the extreme south. In less than five months Ross returned to report the extraordinary results of his expedition.

Fully informed concerning the discoveries of Wilkes, he determined to seek high latitudes to the east of the Balleny Islands, and with little difficulty sailed into a new sea and discovered land extending from Cape Adare to the volcanoes of Erebus and Terror, 77° S.,—a distance north and south of approximately 400 miles. He thus reached a point considerably farther south than that attained by any previous explorer. These discoveries, taken conjointly with those of Wilkes, indicated the probability of the existence of a large polar land mass.

Ross plotted a part of the shore line of that portion of the Antarctic Continent now known as Victoria Land. Returning, he crossed the Antarctic Circle near the meridian of 170° W. His course leaves the area of this map at 140° W., reënters it at 130° W., again passes out to the

north, enters it anew near 50° W., and skirts the ice barrier across the mouth of Weddell Sea to the meridian of 20° W. He finally reached England in September, 1843, having been absent for more than four years.

G. S. NARES, 1874

Challenger

[The course is indicated by transverse red and white bands.]

In 1874, the British steamship *Challenger*, equipped for scientific work and carrying an able scientific staff, entered the Antarctic from Kerguelen Island, crossing the Circle near the 80th meridian east, and then followed the drift ice easterly as far as Wilkes Termination Land. The *Challenger* was the first steam vessel to enter the Antarctic, and the first provided with adequate sounding and dredging apparatus. As a result of the *Challenger's* investigations, the existence of an Antarctic continent was proved and the fact that a wealth of animal life covers the floor of the Antarctic seas was established.

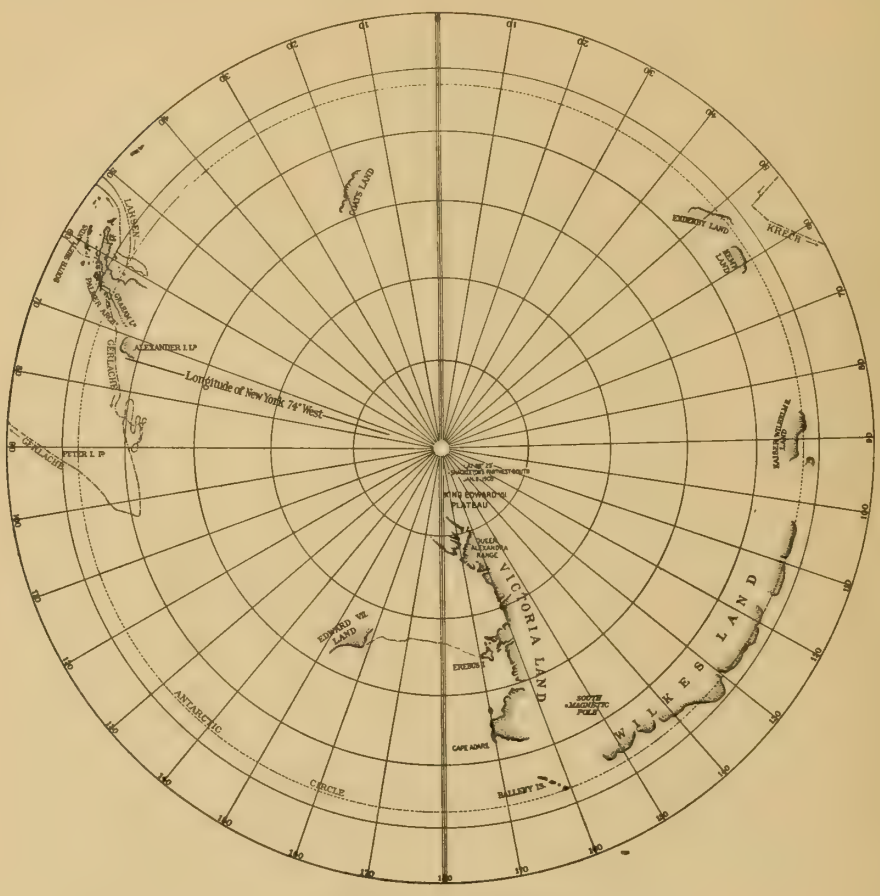
C. A. LARSEN, 1893-1894

Jason

[The course is indicated by red, yellow and blue bands.]

During the last quarter of the nineteenth century, with the waning of the whaling industry in the north and with the report of the existence of large numbers of whales in the south, the small steam whalers of Scotland and Scandinavia made several expeditions into the Antarctic. Among these was the *Jason*, commanded by C. A. Larsen, the same vessel and the same captain that a few years before had left Nansen on the east coast of Greenland. The *Jason* landed south of the South Shetlands and Larsen discovered the

first Antarctic fossils (mollusks and coniferous wood). Previous to this, samples of rock from the Antarctic had been igneous in origin. The fossils proved that at least part of this region was not volcanic.



ANTARCTIC REGIONS

ROUTES FOLLOWED BY C. A. LARSEN, 1893–1894; ADRIEN DE GERLACHE, 1898–1899; ADALBERT KRECH, 1898–1899

The following year Larsen returned to the Antarctic, discovered King Oscar II Land, and forced the *Jason* (the second steamer to cross the Antarctic Circle) to a point 68° 10′ S., roughly exploring the eastern coast of

Graham Land. He discovered two active volcanoes near 65° S.

The *Jason* subsequently was renamed the *Stella Polare* and carried the Duke of the Abruzzi's Arctic expedition to Franz Josef Land, whence Captain Cagni, in 1900, made the nearest approach to the North Pole that had been accomplished up to that time.

LEONARD KRISTENSEN, 1894-1895

Antarctic

[The course is not indicated.]

In November, 1894, the steam sealer and whaler *Antarctic*, under Leonard Kristensen, sailed south from New Zealand with C. E. Borchgrevink, who took passage as a common sailor, and entered Ross Sea. The *Antarctic* followed, in part, the course taken fifty-five years before by Ross. The party landed on Possession Island and discovered a lichen—the first evidence of terrestrial plant life obtained within the Antarctic Circle. A few days later the first landing on the Antarctic Continent was made at Cape Adare. As whales of commercial value were not found, the *Antarctic* returned.

ADRIEN de GERLACHE, 1898-1899

Belgica

[The course is indicated by red, yellow and black bands.]

Belgium now entered the field of Antarctic work. Adrien de Gerlache, a lieutenant in the Belgian navy, left Tierra del Fuego on the *Belgica* in January, 1898, with several scientists and with Dr. F. A. Cook of Brooklyn as ship's surgeon. The Belgians ran the first line of soundings from Cape Horn to the South Shetlands. The naturalists made

many landings, taking photographs and collecting natural history specimens from the shores of Palmer and Graham Lands. In their zeal to explore still farther south, they were caught in the ice at 71° 30′ S., and were the first explorers to pass the winter within the Antarctic Circle.

ADALBERT KRECH, 1898-1899

Valdivia

[The course is indicated by diagonal red, white and black bands.]

The *Valdivia*, of the Hamburg-American Line, commanded by Adalbert Krech, was carefully fitted out for scientific work by Professor Chun of Leipzig. Her first important problem was to determine the existence or non-existence of Bouvet Island, which had been sought in vain by Cook, Ross and Moore, and had not been seen for seventy-five years. It was found 54° 26′ S., 3° 24′ E. The *Valdivia* then proceeded towards Enderby Land, and thence to Kerguelen Island, making important soundings and dredgings.

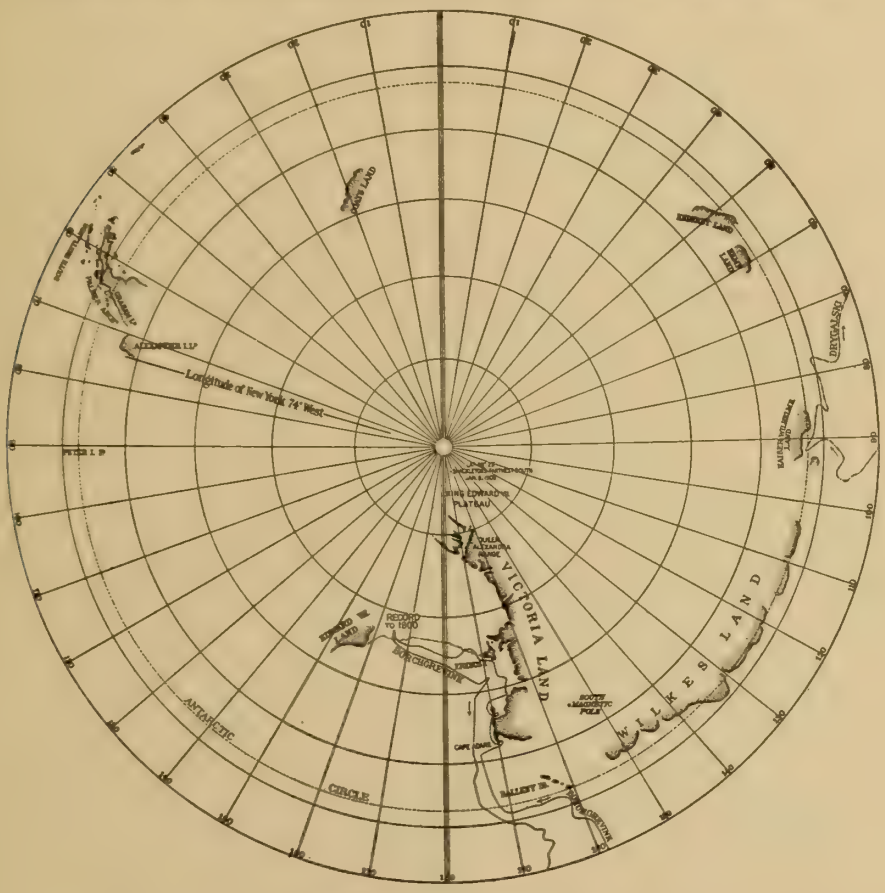
C. E. BORCHGREVINK, 1899-1900

Southern Cross

[The course is indicated by red, alternately narrow and broad, and white bands.]

In February, 1899, C. E. Borchgrevink, a member of Kristensen's expedition of 1894, determined to spend the winter in the Antarctic and again crossed the Circle—this time not as a sailor, but in command of an English expedition. He landed with his party of ten on Victoria Land, near Cape Adare, and bade adieu to his vessel, the *Southern Cross*, which sailed for warmer latitudes, to return at the close of the Antarctic winter. The unhappy members of the

Belgian expedition on the opposite side of the Pole were endeavoring to extricate themselves at the very time Borchgrevink and his companions entered winter quarters. The season was severe and the *Southern Cross* was most welcome on her return, January 28, 1900. A course was then



ANTARCTIC REGIONS

ROUTES FOLLOWED BY C. E. BORCHGREVINK, 1899–1900; ERICH VON DRYGALSKI, 1902–1903

taken still farther to the south along the coast of Victoria Land. Landings were made and the shore of Ross Sea (78° 21′ S.) was reached. A brief sledge trip reached 78° 50′ S. The party then sailed north for Auckland.

ERICH von DRYGALSKI, 1902-1903

Gauss

[The course is indicated by transverse red, white and black bands.]

Professor Drygalski's expedition was made in the German barkentine, *Gauss*, which was designed for strictly scientific work. She was modeled on the lines of the *Fram* and manned by men who had had polar experience. The *Gauss* sailed from Kerguelen Island and in February, 1902, entered the pack near Wilkes Termination Land. Land was soon sighted, but the vessel was caught in the ice and Drygalski was compelled to enter winter quarters. Sledge parties and views from a balloon located Kaiser Wilhelm II Land. The party was liberated the following February and returned to Germany. The collections of the *Gauss* are now being worked up.

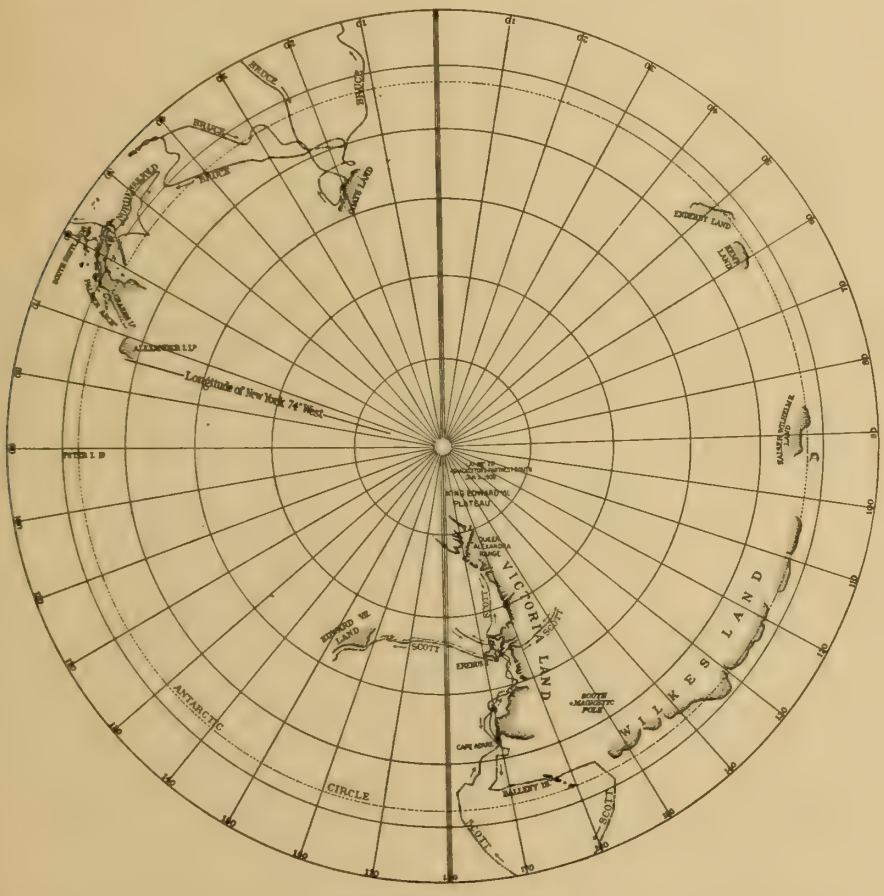
OTTO NORDENSKJÖLD, 1902-1903

Antarctic

[The course is indicated by red and blue bands with yellow dots.]

The geologist, Otto Nordenskjöld, nephew of the Swedish Arctic explorer, Baron A. E. von Nordenskjöld, obtaining funds from his countrymen, secured Kristensen's vessel, the *Antarctic*, engaged C. A. Larsen (earlier attached to the *Jason*), and leaving the South Shetlands in January, 1902, explored in the neighborhood of King Oscar II Land. Landing with three companions to spend the winter on Snow Hill Island, he directed the *Antarctic* to explore in lower latitudes and to return the following spring. The season was very severe. The following spring the *Antarctic*, unable to reach Snow Hill Island, was crushed in the ice and lost. In the meantime, the *Uruguay*, a relief vessel which had been sent out by the

Argentine Government, reached Nordenskjöld on November 8, 1903. The same day Larsen appeared in camp with five of his companions and reported the fate of the *Antarctic*.



ANTARCTIC REGIONS

ROUTES FOLLOWED BY OTTO NORDENSKJÖLD, 1902–1903; R. F. SCOTT, 1902–1904; W. S. BRUCE, 1903–1904

It may be of interest to the visitor to know that Mr. Frank Wilbert Stokes, the artist of the mural paintings in the Eskimo Hall, was a member of this expedition.

R. F. SCOTT, 1902-1904

Discovery

[The course, in part, is indicated by diagonal white and red bands.]

The *Discovery*, under Captain R. F. Scott, a new and well-equipped vessel, manned by officers of the British navy and bearing a scientific staff of well-qualified men, crossed the Antarctic Circle in January, 1902, proceeded to Cape Adare, along the coast of Victoria Land, thence east beyond the point reached by Ross, and discovered Edward VII Land. Captain Scott then returned and placed the *Discovery* in winter quarters near Mount Erebus, where the season was pleasantly spent. On November 2, Scott, Shackleton and Wilson began their heroic sledge journey over the polar ice cap to the south, a distance of 380 miles from their ship. They planted the British flag at 82° 17′ S.

On January 25, 1903, Captain Colbeck of the relief ship *Morning* sighted the *Discovery* and, since the latter vessel could not be freed from the ice, stores were left and the *Discovery* party spent its second winter in the Antarctic. The cold was intense—frequently 50° below zero, and even 68°, was registered. During the spring, Scott and his party traveling westerly reached a position on the elevated plateau of the Antarctic Continent 9,000 feet above sea level. On January 5, 1904, the relief ship *Morning* again appeared, accompanied by another and larger vessel, the *Terranova*. For a while it was thought that the *Discovery* must be abandoned, but on February 16 she was released and sailed for home, thus concluding what must be considered an expedition of extraordinary success.

W. S. BRUCE, 1903-1904

Scotia

[The course is indicated by red and blue bands.]

In 1902, the Scotchman, W. S. Bruce, who was in the Antarctic in 1893 and in the Arctic on the Jackson-Harmsworth expedition in 1894–1897, induced certain of his countrymen to provide funds to equip the *Scotia*, a small Norwegian whaler. He left the South Orkneys early in February, 1903, crossed the Antarctic Circle and made extensive soundings. He wintered on the South Orkneys. In January, 1904, additional soundings were begun and, proceeding south, land was discovered in 74° 1′ S., 22′ W. It was named Coats Land, in recognition of support furnished the expedition by the Messrs. Coats, the famous thread manufacturers.

JEAN CHARCOT, 1903-1905

Français

[The course is not indicated.]

Dr. Jean Charcot, anxious because Nordenskjöld had been obliged to spend a second winter in the south, built the *Français* and organized a relief expedition. He met the Argentine Relief Expedition as it was returning with the Nordenskjöld party. Determining, however, that the *Français* should do some Antarctic work before her return, he remained in the South during the seasons of 1903 to 1905, charting the western coast of the islands of the Palmer Archipelago.

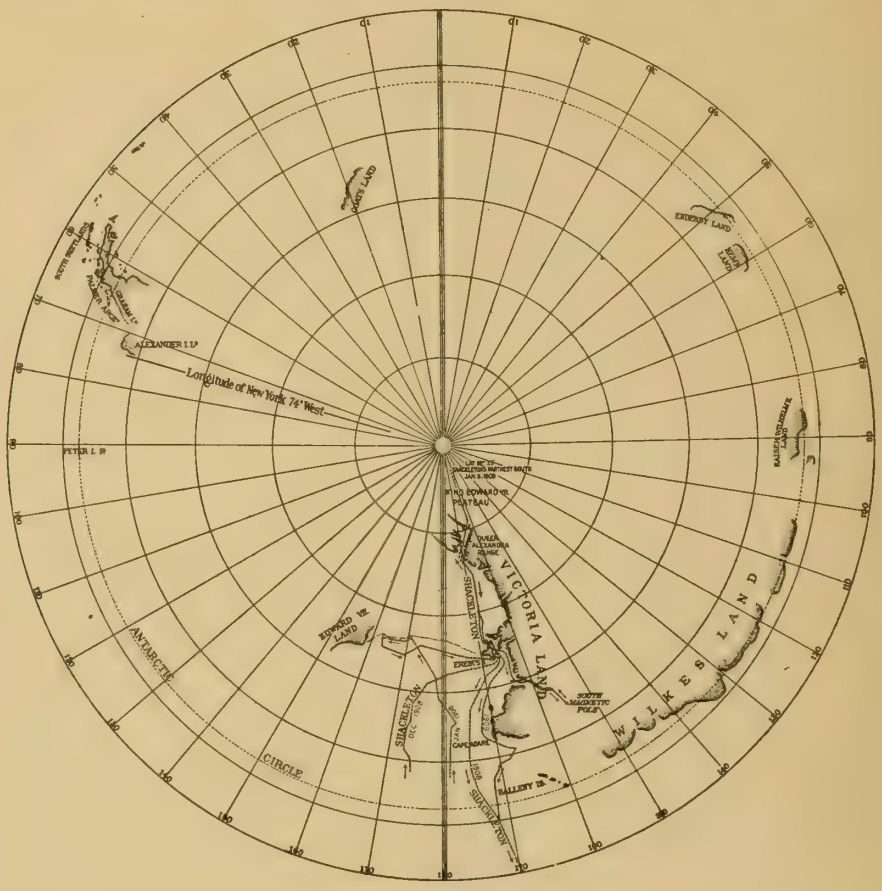
E. H. SHACKLETON, 1908-1909

Nimrod

[The course, in part, is indicated by red, white and narrow blue bands.]

Early in 1908, Lieutenant Shackleton on board the *Nimrod*, with a party of about fifteen men, dogs, Siberian

ponies, a motor car and other equipment, entered the Antarctic regions near the 180th meridian. Passing through Ross Sea and along the edge of the great ice barrier, they almost reached King Edward VII Land, but found further progress in that direction blocked by impenetrable



ANTARCTIC REGIONS

ROUTE FOLLOWED BY E. H. SHACKLETON, 1908–1909

pack-ice. They then proceeded to Cape Royds near the volcano, Mount Erebus. Here the *Nimrod* left them and went north, to return the following spring. Relatively elaborate winter quarters were established at Cape Royds

in a specially designed hut made of cork. In March, 1908, a party of six ascended Mount Erebus to its summit, 13,500 feet above sea level.

On October 5, 1908, a party of five started on its journey to the South Magnetic Pole, which was reached on January 16, 1909. The position of the magnetic pole was determined to be 72° 25′ S., 155° 16′ E. The south point of the compass always turns towards this point. Therefore, between the South Magnetic Pole and the South Geographic Pole the south point of the compass is directed due north. This party, returning to the coast February 3, was picked up by the *Nimrod* and taken to Cape Royds.

On October 29, 1908, Shackleton and three others—with a supporting party of five, which turned back November 7—set out for the South Geographic Pole. They followed, roughly, the 168th meridian east until in late November they reached Scott's farthest south—82° 17′ S. Christmas day found them at 85° 55′ S., and by 9:00 A.M., January 9, 1909, they had reached 88° 23′ S. Beyond this point they could not go on account of the hard traveling and the exhaustion of their food supply. No mountains were visible beyond, and it is probable that the South Pole is situated on a level plateau 10,000 to 11,000 feet above sea level. After an extremely hard return journey on short rations, Cape Royds was reached March 4, 1909. The *Nimrod* and the supporting and relief parties were there waiting, and the next day all started for home.

In addition to discovering the South Magnetic Pole and reaching a point within 110 miles of the South Geographic Pole, the main results of the journey were the finding of coal (showing that in the past this region enjoyed a mild climate), the procuring of a complete meteorological record and the discovery of eight distinct mountain ranges varying from 3,000 to 12,000 feet in altitude.

THE AMERICAN MUSEUM JOURNAL

EDMUND OTIS HOVEY, *Editor*
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No. 3.—THE HALL OF FOSSIL VERTEBRATES. By W. D. MATTHEW, Ph.D., Assistant Curator of Vertebrate Palæontology. January, 1902. *Out of print.*

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No. 17.—THE FOSSIL CARNIVORES, MARSUPIALS AND SMALL MAMMALS IN THE AMERICAN MUSEUM OF NATURAL HISTORY. By W. D. MATTHEW, Ph.D., Associate Curator of Vertebrate Palæontology. January, 1905. *Price*, 15 *cents*.

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No. 30.—THE STOKES PAINTINGS REPRESENTING GREENLAND ESKIMO. November, 1909. *Price*, 5 *cents*.

No. 31.—A BRIEF HISTORY OF ANTARCTIC EXPLORATION. March, 1910. *Price*, 10 *cents*.

AMERICAN MUSEUM OF NATURAL HISTORY

Trees and Forestry

FLOWER AND LEAVES OF THE TULIP-TREE

PORTION OF MODEL IN THE FORESTRY HALL

NO. 32 OF THE GUIDE LEAFLET SERIES—SEPTEMBER, 1910

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WHITE PINES

On the estate of the late Morris K. Jesup, Lenox, Massachusetts

TREES AND FORESTRY

AN ELEMENTARY TREATMENT OF THE SUBJECT BASED ON THE

Jesup Collection of North American Woods

IN THE

AMERICAN MUSEUM OF NATURAL HISTORY

By MARY CYNTHIA DICKERSON, B. S.
Curator of Woods and Forestry

NEW YORK
Published by the Museum
September, 1910

NO. 32

OF THE

GUIDE LEAFLET SERIES

OF THE

AMERICAN MUSEUM OF NATURAL HISTORY

MARY CYNTHIA DICKERSON, Editor

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PREFATORY NOTE

The author expresses gratitude to all those who have extended courtesies during the preparation of this *Leaflet*. Especially are thanks due to the Honorable Gifford Pinchot, President of the National Conservation Association and to Professor J. H. Toumey, Director of the Yale Forest School, who as members of the Appointive Committee on Woods and Forestry of the American Museum read the *Leaflet* in proof and gave valuable suggestions; also to the United States Forest Service and Doubleday, Page and Company, who allowed the use of photographs for many of the half-tones. Primarily, of course, indebtedness is due to the Forest Service, since much of the subject matter concerning practical points has been compiled from its work.

The pamphlet has been made to cover a wide field in order not to lack in suggestiveness along the various lines of interest of the Museum's visitors; thus of necessity it touches many matters briefly. Again forestry is so rapid-growing a subject to-day that even a few months are likely to put out of date these briefly stated facts along certain practical lines. The latest information of markets and methods as well as of legislation on conservation at home and trade relations with foreign countries must always be sought in later publications, such as Government bulletins and the monthly periodical of the American Forestry Association.

The chapter intended to help in the identification of trees in their winter condition, although covering trees represented by an armful of twigs which one might gather in the Eastern United States, is so incomplete that it has been given a subordinate place as an appendix. The line cuts for this chapter were made from freshly gathered material, under the supervision of the author, by Miss Alma Field of the Rhode Island School of Design, Providence.

American Museum of Natural History, *September, 1910.*

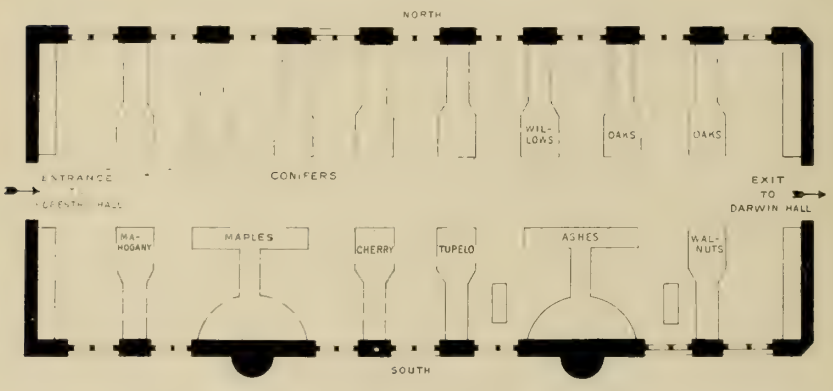

DIAGRAM OF THE FORESTRY HALL, FIRST FLOOR, EAST FROM THE MAIN FOYER
AMERICAN MUSEUM OF NATURAL HISTORY

The Forestry Hall contains the Jesup Collection of Woods representative of the five hundred species of North American trees. These woods are arranged in related groups or families, the specimens of large market value holding prominent place in each group

SOME BOOKS ON TREES AND FORESTRY

Boulger, Geo. S. Wood. London: Longmans, 1902. $3.00

Dame, L. L. and Brooks, H. Trees of New England. Boston: Ginn, 1902. $1.50

Fernow, B. E. The Care of Shade Trees. New York: Holt, 1910. $2.00

Economics of Forestry. New York: Crowell, 1902. $1.50

Forest Service, U. S. Department of Agriculture, Washington.

Fox, W. F. and Hubbard, W. F. The Maple Sugar Industry. Bulletin No. 59. 1905. Free

Graves, H. S. Practical Forestry in the Adirondacks. Bulletin No. 26. 1899. Free

The Woodman's Handbook. Bulletin No. 36. 1903. Free

Graves, H. S. and Fisher, R. T. The Woodlot. Bulletin No. 42. 1903. Free

Herty, Charles F. A New Method of Turpentine Orcharding. Bulletin No. 40. 1904. Free

Hubbard, Wm. F. The Basket Willow. Bulletin No. 46. 1904. Free

McClatchie, A. J. Eucalypts Cultivated in the United States. Bulletin No. 35. 1902. $1.00

Pinchot, Gifford. A Primer of Forestry. Part I — The Forest. 35 cents; Part II — Practical Forestry. 30 cents

Roth, F. Timber: an Elementary Treatise on the Characteristics and Properties of Wood. Bulletin No. 10. 1895. Free

Sherfesee, W. F. Wood preservation in the United States. Bulletin No. 78. 1909

Sudworth, Geo. B. Check List of Forest Trees of the United States. Bulletin No. 17. 1898. 15 cents

Forest Influences. Bulletin No. 7. 1892. Reprinted, 1902. 15 cents

A Short Account of the Big Trees of California. Bulletin No. 28. 1900. 10 cents

Fürst, H. The Protection of Woodlands (John Nisbet *trans.*) New York: Jenkins, 1893. $3.50

Graves, H. S. Forest Mensuration. New York: Wiley, 1906. $4.00

Green, S. B. Principles of American Forestry. New York: Wiley, 1903. $1.50

Hough, R. B. Handbook of Trees of the Northern States and Canada. New York: Hough, 1907. $6.00

Marsh, G. P. The Earth as Modified by Human Action. New York: Scribners, 1898. $3.50

Parkhurst, H. E. Trees, Shrubs and Vines of the Northeastern United States. New York: Scribners, 1903. $1.50. (Gives the trees of Central Park, New York)

Roth, F. A First Book of Forestry. Boston: Ginn, 1902. 75 cents

Sargent, C. S. Manual of the Trees of North America. Cambridge: Riverside Press, 1905. $6.00

The Silva of North America. Cambridge: Riverside Press, 1891–1902. 14 vols. $350

Schlich, Wm. Manual of Forestry. London: Bradbury, Agnew. 1894–1902. 5 vols. $17.20

Schwappach, A. Forestry. New York: Macmillan, 1905. 50 cents

Snow, C. H. Principal Species of Wood. New York: Wiley, 1903. $3.50

Stone, Herbert. The Timbers of Commerce. London: Rider, 1904. $3.00

Van Hise, C. R. Conservation of Natural Resources in the United States. New York: Macmillan, 1910. $2.00

FIG. I. FLOWERS AND FRUITS OF THE PAPAW (*Asimina triloba*)

Portions of the models in Forestry Hall, Case E, 3. The wine-colored flowers bloom in April; the fruit is ripe in September and October. Wood inferior. Tree planted for ornament

TREES AND FORESTRY

Prepared for use with the Jesup Collection of North American Woods

INTRODUCTION

THE Morris K. Jesup Collection of North American Trees, in the Forestry Hall of the American Museum of Natural History, is designed for the student, artisan and forester, and for the man commercially interested in woods, as well as for those who enjoy familiarity with the woodland and wish to increase their enjoyment by extending their familiarity.

The collection was begun by Mr. Jesup in 1880, and throughout his presidency of twenty-seven years, it received his constant attention. Indeed, in its completeness and attractiveness, its scientific correctness and educational value, it is a splendid example of what he desired an exhibition in a scientific and educational institution to be. In its now practically perfected condition, it displays in related groups or families more than five hundred species of the trees of North America. Each tree is represented by a section of trunk 5 feet high, cut lengthwise radially $2\frac{1}{4}$ feet, the cut surface showing the color and graining of the quartered lumber in its natural and polished state (see Figs. 2, 5, 6 and 42). Also for the more common trees, there is a separate piece of the wood which may be handled and tested for lightness, softness, resonance, odor and other qualities.

One of the most remarkable features of the collection lies in its accompanying models of tree leaves, flowers and fruits (see Cover and Figs. 1, 2, 5, 6 and 42). So perfectly are the representations executed that it is often impossible to discover even by careful scrutiny how much may be original and how much reproduced. There are flowers of the decorative magnolias, of basswood interesting to bee keepers, curious fruits of sassafras, persimmon, and Osage orange, autumn foliage of oak, sweet gum and sumach.

This leaflet is designed to accompany the Jesup Collection of Woods, emphasizing its great commercial value by adding practical suggestions for the growth of trees. It presents the status of the forest conservation question in the year 1910.

FIG. 2. FLOWERING DOGWOOD (*Cornus florida* LINN.)

New England to Florida, westward to Minnesota and Texas. Wood, often called boxwood, unusually heavy, tough, strong and hard, receiving high polish, suitable for use in carving, engraving, turnery and for bearings of machinery; used largely for shuttles in the textile industry. Forestry Hall, Case E, 7

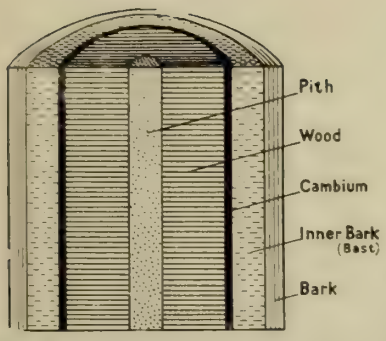

FIG. 3. STRUCTURE OF A TREE TRUNK ONE YEAR OLD

It is a series of cylinders one within another. The cambium is the living part

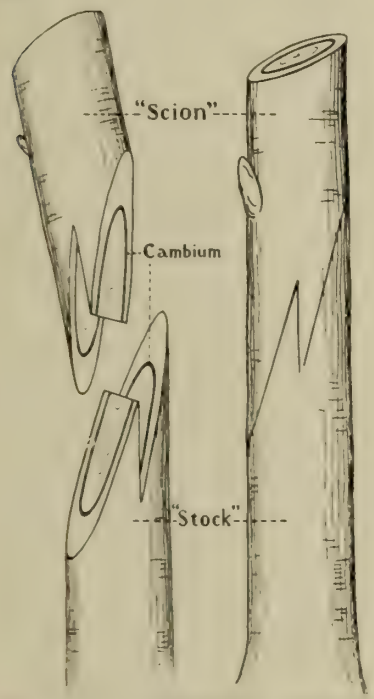

FIG. 4. KEY TO SUCCESS IN GRAFTING

The living cambium of the "scion" must join exactly and become continuous with the living cambium of the "stock," or the process will not be successful

STRUCTURE AND LIFE OF A TREE

A TREE is an individual and as such it is alive, with parts dividing the labor pertaining to life and coöperating for the good of the whole; but, on the other hand, a tree has only a small fraction of its great mass made up of living substance. When very young, it consists entirely of living substance; but long before one year has passed it contains a large accumulation of dead material the great bulk of which is "wood," filling up and making strong the trunk, branches and roots.

The one-year old trunk, examined from the central axis to the outside, has a definite structure as follows: (1) a rod of *pith*, (2) a cylinder of *wood* embracing the pith, (3) a cylinder of *inner bark* (*bast*), thinner-walled than the wood cylinder and embracing it, and outside of these, (4) an enfolding cylinder of *bark* (Fig. 3). All send off parts to right and left into the leaves and, after the first year, into the branches. The living part, called the *cambium*, a living cylinder of scarcely appreciable thickness, lies between the wood and the inner bark. It is easy to understand why, in grafting, the living layer of the branch to be attached must be made to join exactly and become continuous with the living layer of the branch which is to receive it, or the grafting will not be successful (Fig. 4).

Each year this living cylinder of

FIG. 5. WILD PLUM (*Prunus americana* MARSH)

New York to Texas and Colorado. Good stock on which less hardy varieties are grafted. Wood heavy, hard, strong and close-grained. Forestry Hall, Case D, 10

FIG. 8. OSAGE ORANGE, ILLUSTRATING "HEARTWOOD" AND "SAPWOOD" 13

The formation of the heartwood follows very rapidly on the growth of sapwood so that the latter is only a narrow layer of lighter wood next the bark. The cambium and inner bark are too narrow to be defined in the photograph. Forestry Hall, Case F, 20 (*Toxylon pomiferum* Raf.)

cambium produces new wood everywhere on its inner surface (living material while forming, non-living when formed), a cylinder of new wood enfolding immediately the wood of the year before (Fig. 7). Wood never lengthens after once formed, so a trunk grows in height only by additions from living buds at the top (Fig. 8), but a tree grows in diameter annually by just the thickness of the new cylinder of wood (a ring of wood when seen at the end). The thickness of the annual layer in any species depends on the length of the growing season in the given region and on the age of the tree, those wood cylinders formed in early life being relatively thick-walled and later ones successively more and more thin-walled. A further fact is true, however, and to be remembered in economic tree planting, that the diameter increase of any tree is always immediately dependent on its growing space, on soil, light and other conditions of the surroundings, factors which to a large extent we can control.

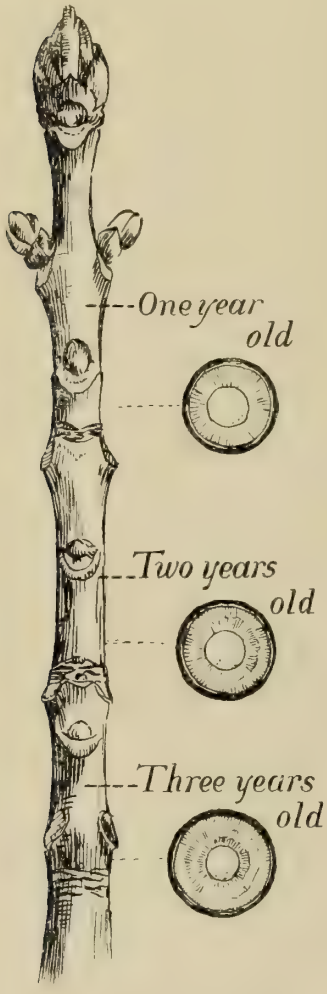

FIG. 7. WHITE ASH TWIG

Cross section to show rings of wood, corresponding to the cylinders of wood in the twig. Compare with Fig. 8

This method of growth places the older wood as "heartwood" in the center of the trunk, while the younger wood, called "sapwood," is outside of this. Heartwood and sapwood may differ in weight and in color, since the heartwood is likely to be a storehouse for coloring matter, or gummy, resinous or mineral substances which have come into the tree from the soil or are the waste from vital processes. Heartwood is more durable than sapwood because it does not often contain starch or other organic matter, and therefore is less liable to the attacks of insects and to the growth of the organisms that cause decay, also on its change from sapwood depositions of material more or less antiseptic take place. Trees in which the formation of heartwood does not follow rapidly on the growth of sapwood are the oaks, elms, walnuts and pines. Some trees

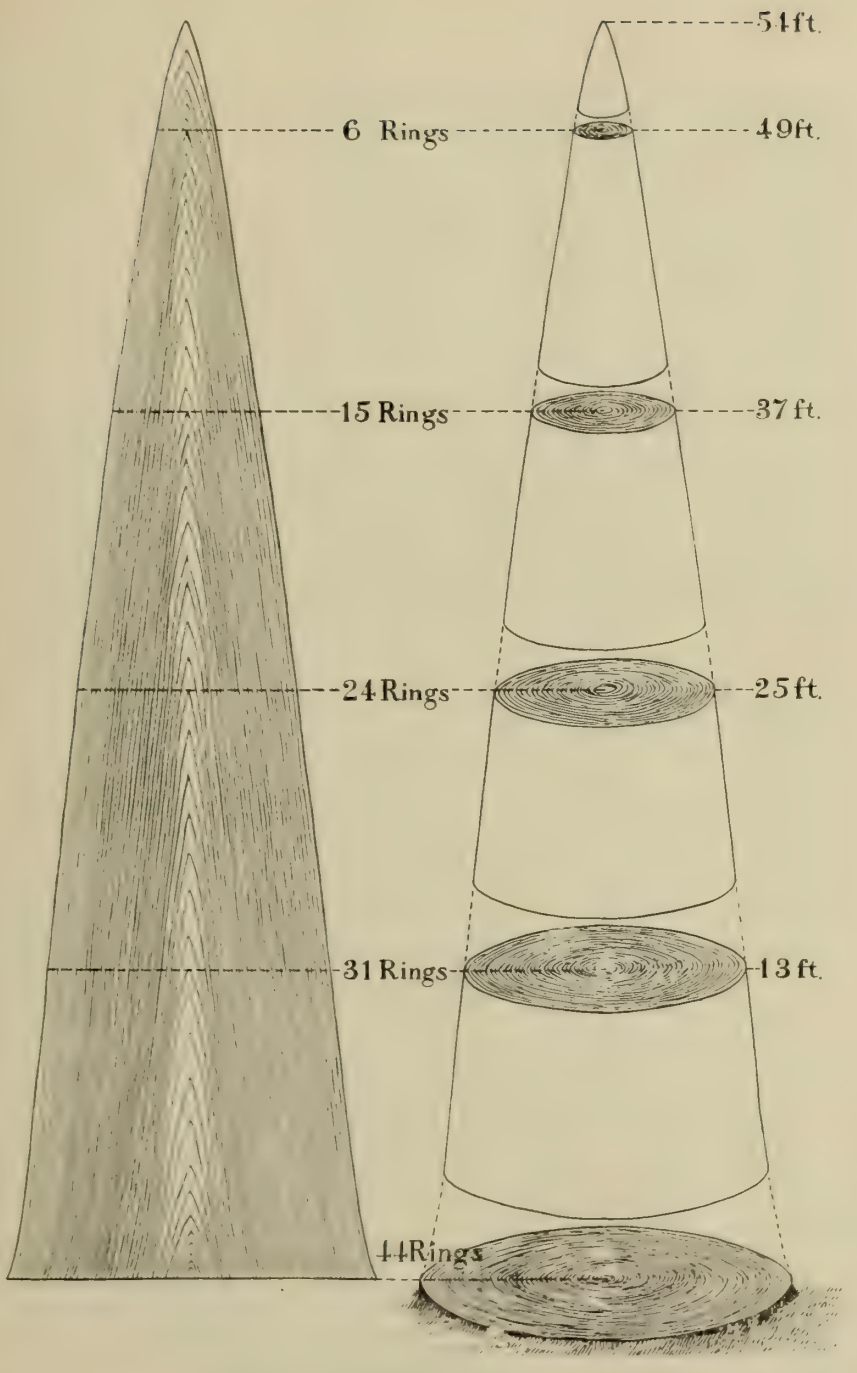

FIG. 8. THE PROGRESSIVE GROWTH OF A TREE 15

A tree grows in diameter each year by the addition of a cone of wood which never increases in height after being formed. Compare with Fig. 7. The age of the trunk is shown at various heights (44 years at the ground, 6 years near the top, corresponding to the number of rings in cross section)

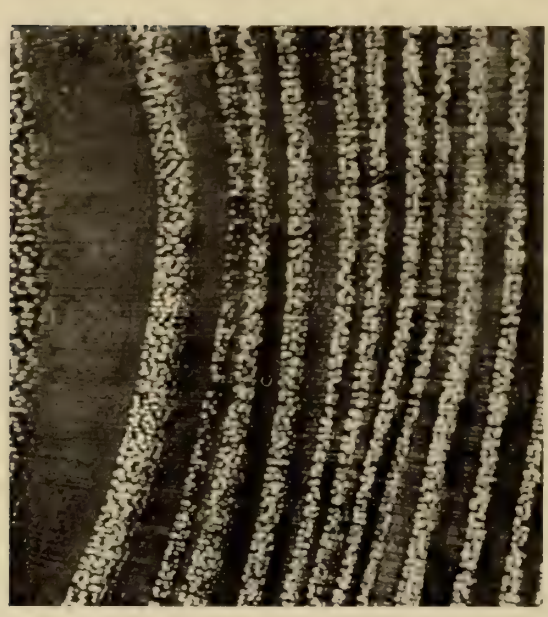

FIG. 9. CROSS SECTION OF CHESTNUT
Showing the porous "spring wood" and more compact "summer wood"

noted for their narrow sapwood are locust, mulberry, Osage orange (Fig. 6), chestnut and larch.

Also in the wood of each cylinder or ring, there may be a differentiation in color and often in structure, that part of the cylinder which grows rapidly in the spring proving light in color and perhaps porous (spring wood) (Figs. 9 and 10). In fact, it is difficult to count the annual rings in birches, hornbeams, maples, poplars and willows, trees in which so little summer wood is made, that the spring wood of one year appears to adjoin the similar spring wood of the next year.

We speak of the beginnings and additions of wood as cylinders, but, in truth, they are cones, as a consideration of Figs. 7 and 8 will prove. A cut through the central part of a log so that the saw practically cuts through a radius of each cone will produce a board with its surface showing wood bands or lines relatively parallel (Figs. 11 and 13; radial or quartered cut of

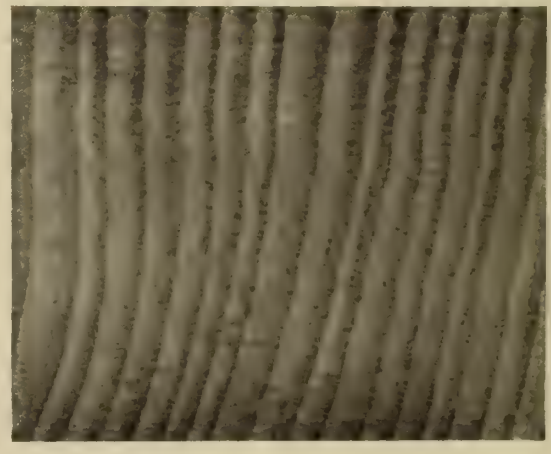

FIG. 10. CROSS SECTION OF DOUGLAS SPRUCE
Indicating variation of spring and summer wood

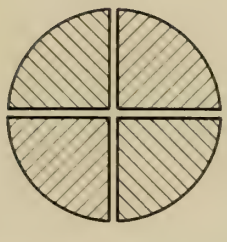

FIG. 11. ONE METHOD OF QUARTER-SAWING

Quartered boards warp and split less than tangential cuts of lumber because cut in the direction of the pith rays. Compare with Figs. 13, 18 and 20

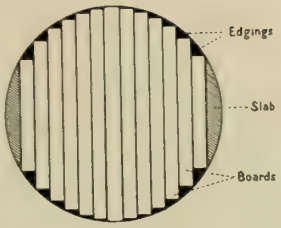

FIG. 12. COMMON METHOD OF SAWING TIMBER

No quartered lumber results, with the exception of a few boards in the middle. There is waste in any method of sawing but charcoal blast furnaces and chemical plants may convert bark, limbs, edgings and even sawdust into some valuable product

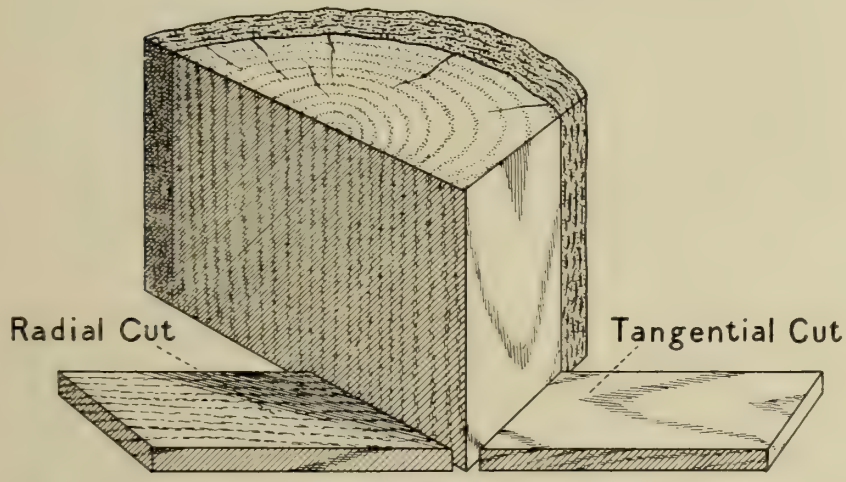

FIG. 13. RADIAL AND TANGENTIAL CUTS OF LUMBER

Boards cut from the central part of a log (and so at right angles to the wood rings and in the direction of the pith rays) produce radial, rift, or quartered lumber; other boards (tangent and oblique to the wood rings and more or less at right angles to the pith rays) give tangential, common, or bastard cuts of lumber. Compare with Figs. 11 and 20

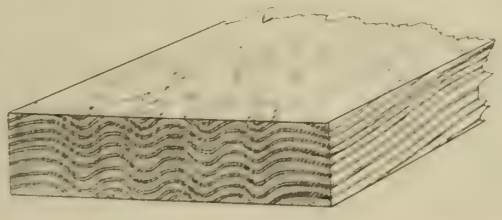

FIG. 14. BIRD'S EYE MAPLE

Occasionally there is a tree in which the wood cylinders have fluted walls. Cutting through these fluted walls produces the "bird's eye" marks on the boards

lumber). In a cut downward through a log some distance out from the center, the saw continually strikes and cuts through the sloping walls of wood cones and the resulting board shows in its midline wood bands appearing as concentric angles or U-shaped figures (Figs. 12 and 13, tangential or bastard cut of lumber). The U-shaped marks may be the result also of irregularity in the growth of the tree due to the effects of sun, prevailing wind or other external agency. Occasionally the wood cylinders for some unknown reason have fluted walls, in which case it is easy to see how a board gains the appearance called "bird's eye," illustrated in hard maple (Fig. 14).

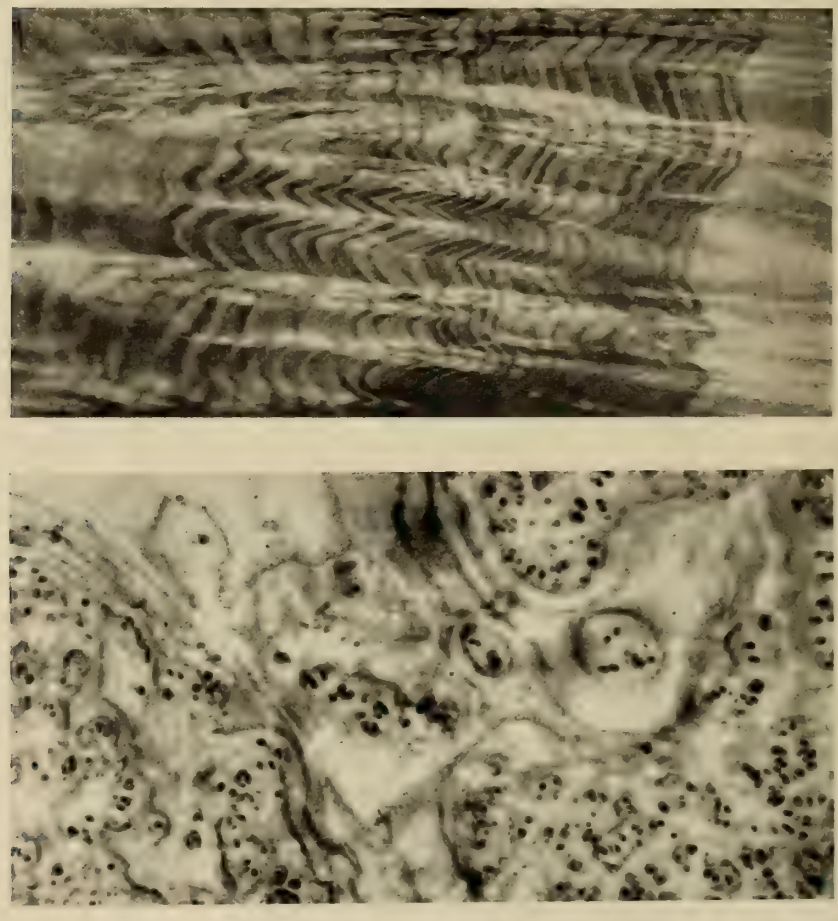

FIG. 15. BLACK ASH BURL

Irregularity of the wood cylinders in burls or knots causes the unusual and often very beautiful effects seen in burl veneers

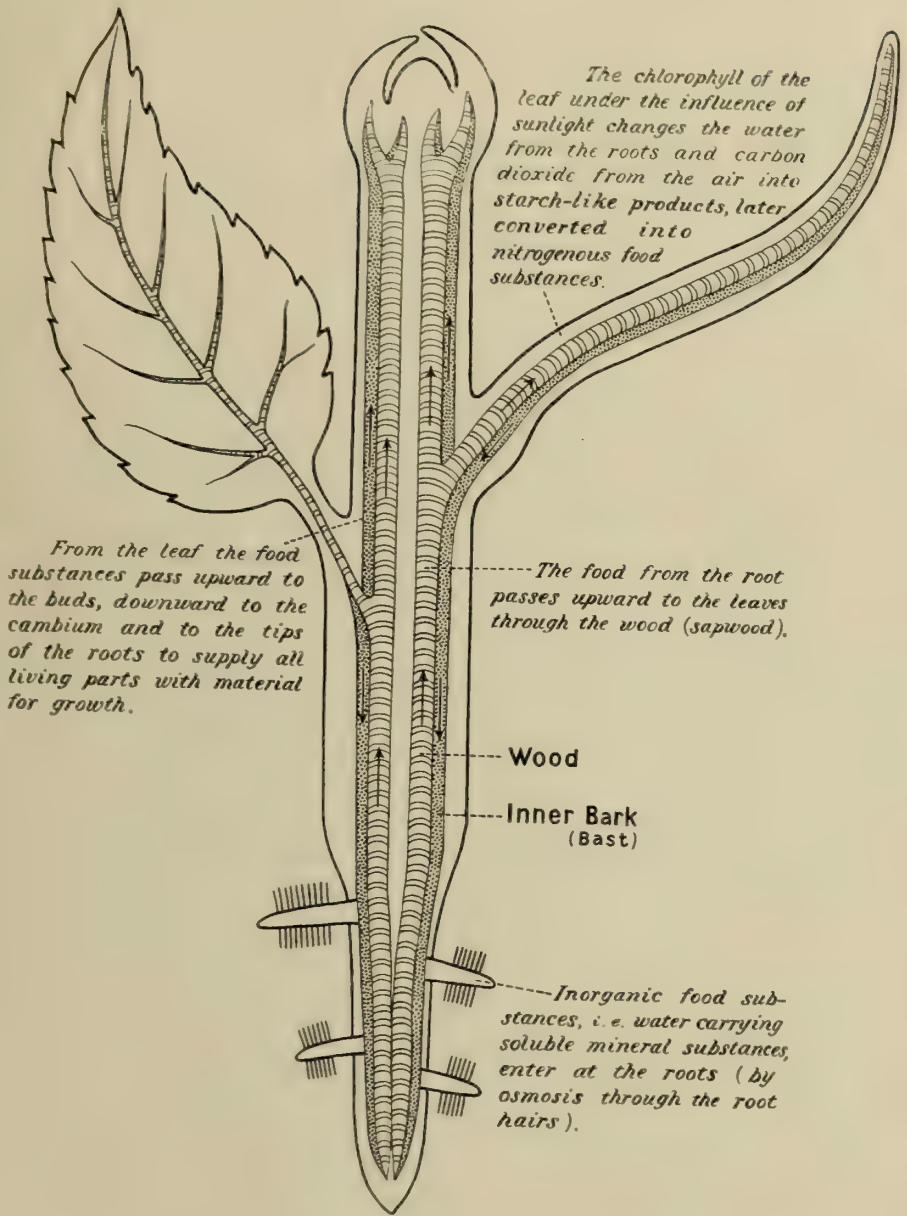
The chlorophyll of the leaf under the influence of sunlight changes the water from the roots and carbon dioxide from the air into starch-like products, later converted into nitrogenous food substances.
From the leaf the food substances pass upward to the buds, downward to the cambium and to the tips of the roots to supply all living parts with material for growth.
The food from the root passes upward to the leaves through the wood (sapwood).
Wood
Inner Bark
(Bast)
Inorganic food substances, i. e. water carrying soluble mineral substances, enter at the roots (by osmosis through the root hairs).

FIG. 16. DIAGRAM SHOWING COURSE OF THE SAP

It passes from the roots through the wood to the leaves, and after its chemical change there, through the inner bark (bast) to all growing parts

Irregularity of the wood cylinders in "burls," overgrown knots and excrescences occasionally found on various trees, causes the unusual and often very beautiful effects seen in burl veneers (Fig. 15).

It is the work of these various tissues in coöperation for the tree's maintenance as an individual that is of most interest. Water containing lime, potash and other minerals in solution, is taken up from the soil through the roots. This food cannot be used directly for growth by the tree any more than it could be by man. It is sent upward through the sapwood to the leaves of the tree. A tree may be girdled, that is, cut to the cambium, and also may be hollow through the whole extent of its heartwood, yet it will live for some time if there is continuous sapwood

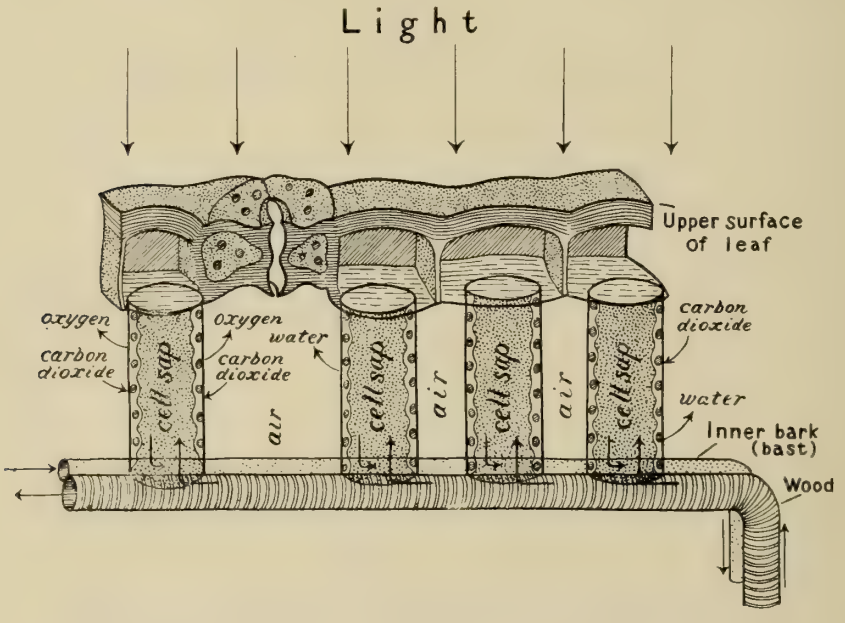

FIG. 17. ACTIVITIES GOING ON IN THE "CELLS" AND AIR SPACES OF A LEAF

(1). Under the sun's heat, water is continually evaporating from the leaf. A tree must lift several thousands of lbs. of water to the leaves to get 1 lb. of mineral matter in solution in the sap. The greater part of this water is evaporated from the leaves. A birch tree gives off 700–1000 lbs. of water daily; a single oak sends off into the air 130 tons of water annually

(2). Carbon dioxide is absorbed continually in daylight by the leaf to make possible the starch-forming process, while free oxygen is at the same time given off as a waste product from this same process. This absorption of carbon dioxide and outpouring of oxygen makes one explanation of the fact that park and street trees increase the healthfulness of a city

from root to leaves. The living green substance (chlorophyll) of the leaves under the influence of sunlight breaks apart the hydrogen and oxygen, elements in this water gained from the roots, and at the same time separates the carbon and oxygen, elements in carbon dioxide gained from the air, and recombines the three, hydrogen, oxygen and carbon, to make various starch-like products. This chemical work of green plants, defying man's efforts to imitate, creates food for animal life on the globe and is, in fact, the only source of that food. Later, the starch is changed to complex substances, largely because of the addition of nitrogen, and passes through the inner bark (bast) of the trunk, upward to give food to the growing buds, downward to supply the living cambium throughout its length with material for a new wood layer, and to give nourishment to the living tips of the roots (Fig. 16).

These plant activities, mechanical and chemical, are not fully understood. Osmosis or the passage of liquids through an organic membrane explains the entrance of water carrying soluble substances into the roots; and since in osmosis the movement is more rapid in the direction of the stronger solution, which in this case is within the roots, the continual passage of water into the roots must create considerable pressure upward. This root pressure accounts in some degree for the rise of water in the trunk. Root pressure in birch trees will lift water in the tree trunk to a height of 84.7 feet. A second force acting to carry the current upward through the sapwood is probably capillarity (the force which causes rise of a liquid through any porous substance). A third force is the strong attraction naturally existing between particles of wood and particles of water. A fourth is certainly the continual and often rapid evaporation of water from the tree's enormous leaf surface which lies spread out under the heat of the sun (Fig. 17).

Other structures of the trunk, complicating an understanding of the appearance of lumber, are short, thin plates made of a substance like the pith, arranged radially and vertically through the wood but irregularly with reference to one another (Fig. 18). These plates, called pith rays, show as radial lines in a cross-section of a log (see upper section, Figs. 19 and 20). They produce what is known as the silver grain of lumber, inconspicuous short lines on the surface of tangential boards because the plates are cut through their length and thickness, but often conspicuous in quartered lumber where, cut through length and width, the plates are sometimes exposed for two or more inches on the board's surface (see lower section, Figs. 19 and 20). The pith rays in different species of trees differ to such an extent that, like the variations of spring and summer wood, they serve to identify different kinds of wood. In oaks the rays are long and

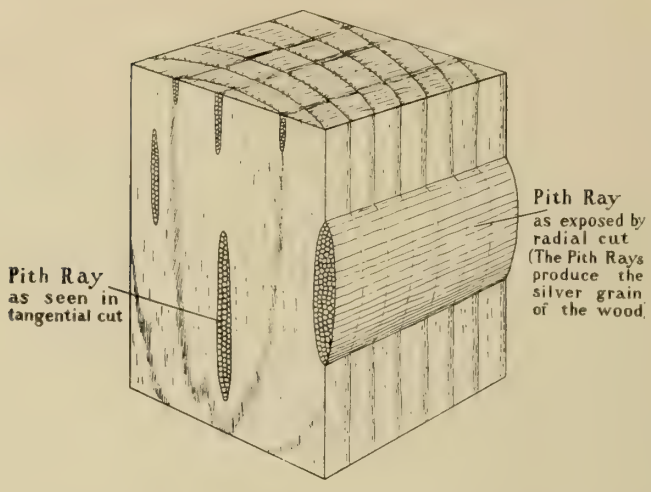

FIG. 18. RELATIVE POSITION OF PITH RAYS AND WOOD RINGS

In a radial cut, the pith rays may show as broad bands (silver grain); in a tangential cut, they appear only as short lines. Compare with Figs. 19 and 20

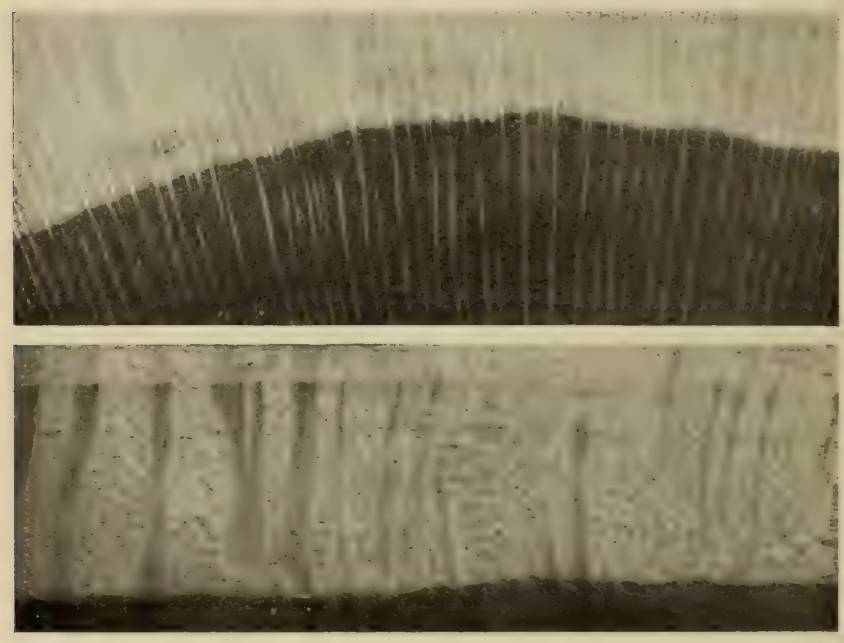

FIG. 19. OAK WOOD SHOWING PITH RAYS

Narrow radiating lines in cross section, broad silvery bands in the quartered wood. Compare with Figs. 18 and 20

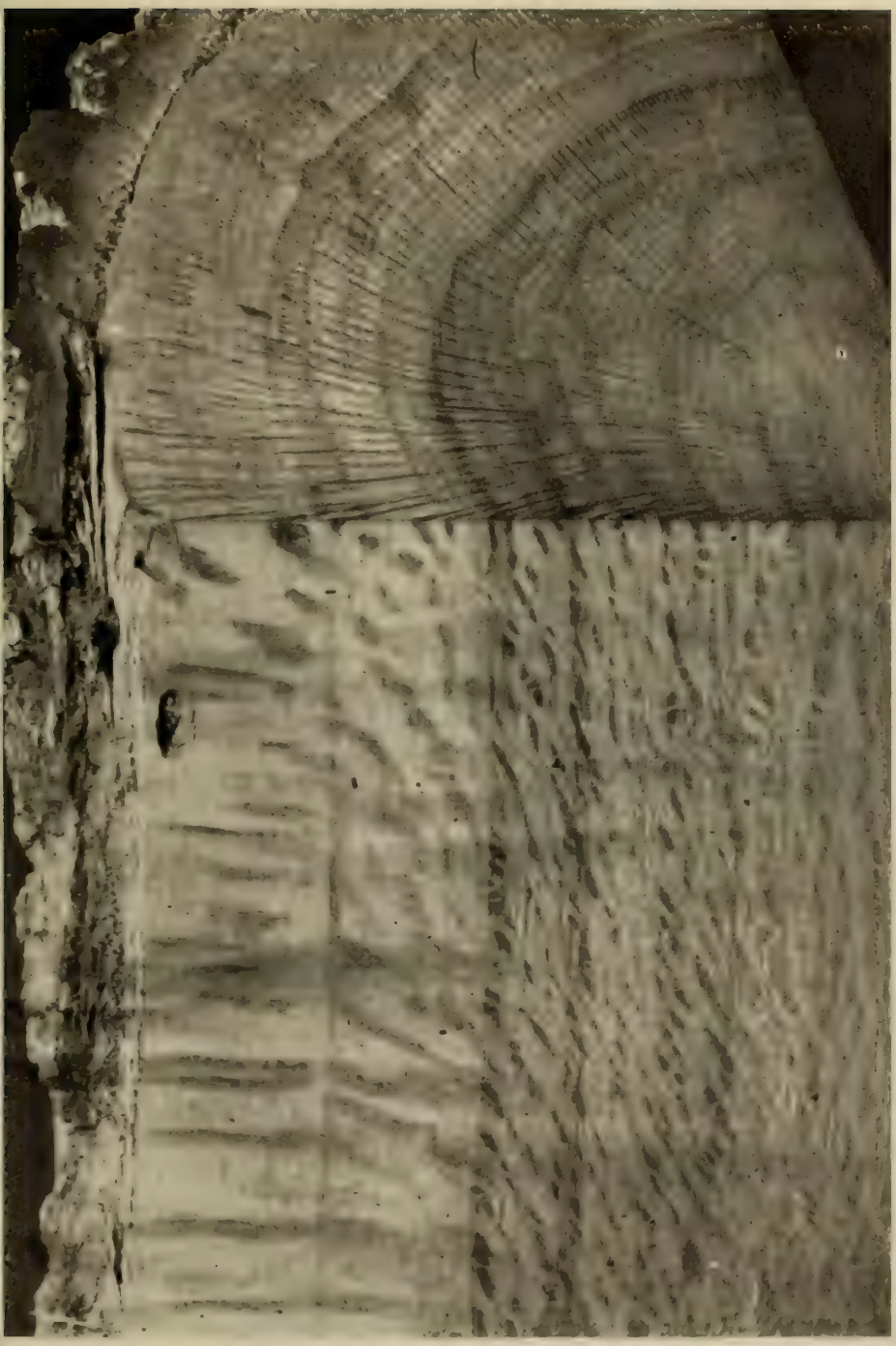

FIG. 20. STUDY OF OAK WOOD 23

Pith rays of a log seen in cross and radial cuts and at the line of meeting of the two surfaces

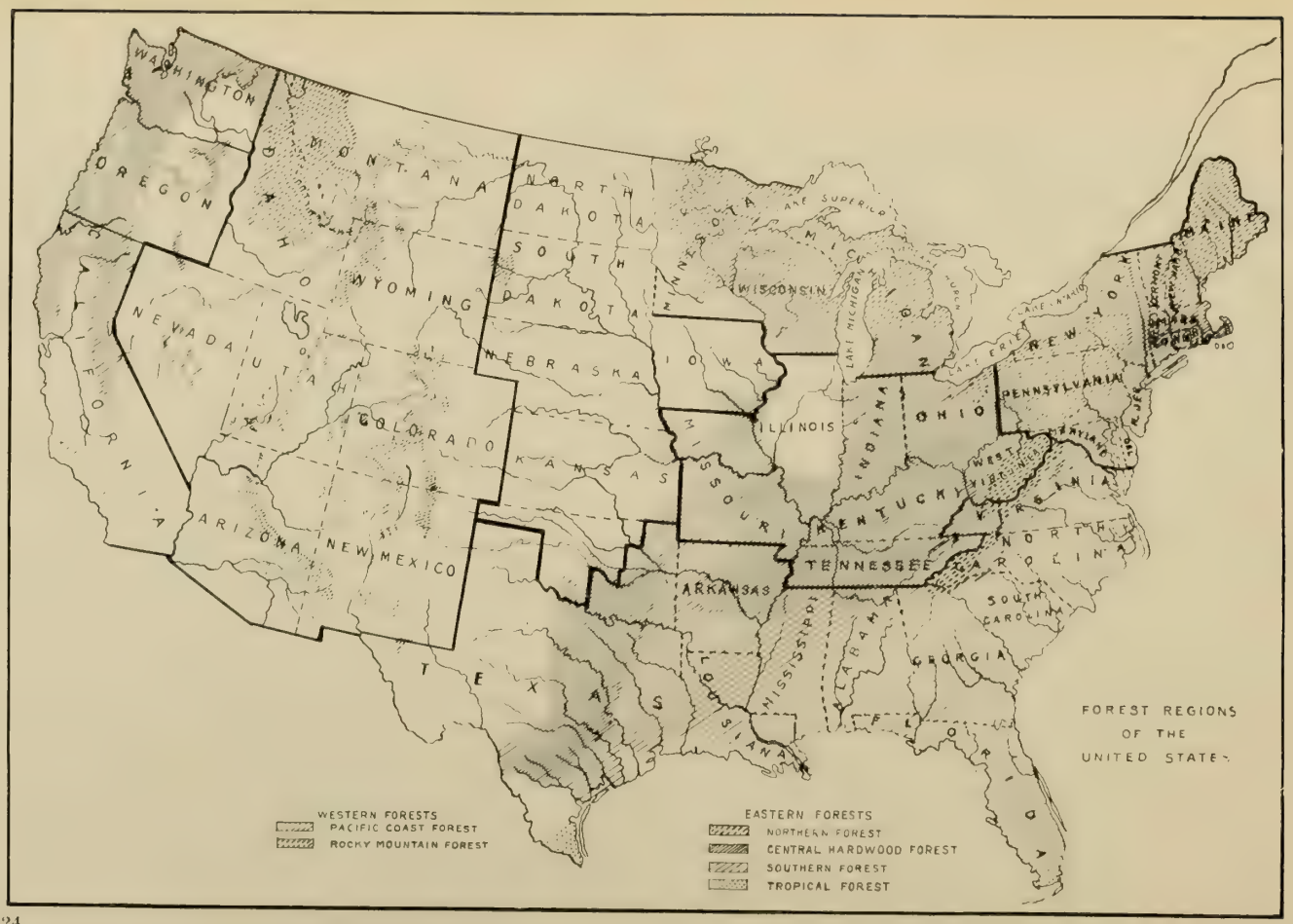

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Fig. 21. *Northern Forest* — Spruce, second-growth white pine, hemlock and hardwoods. *Hardwood Forest* — southern portion, hardwoods; northern, cedar, tamarack, hemlock and white pine. *Southern Forest* — Lowest lands, cypress and hardwoods; next level, southern pine; plateaus and lower mountain regions, pure hardwood; highest ridges, spruce, white pine and hemlock. *Rocky Mountain Forest* — Western yellow and lodgepole pines. *Pacific Forest* — Douglas fir, western hemlock, sugar and western yellow pines, redwood, cedar

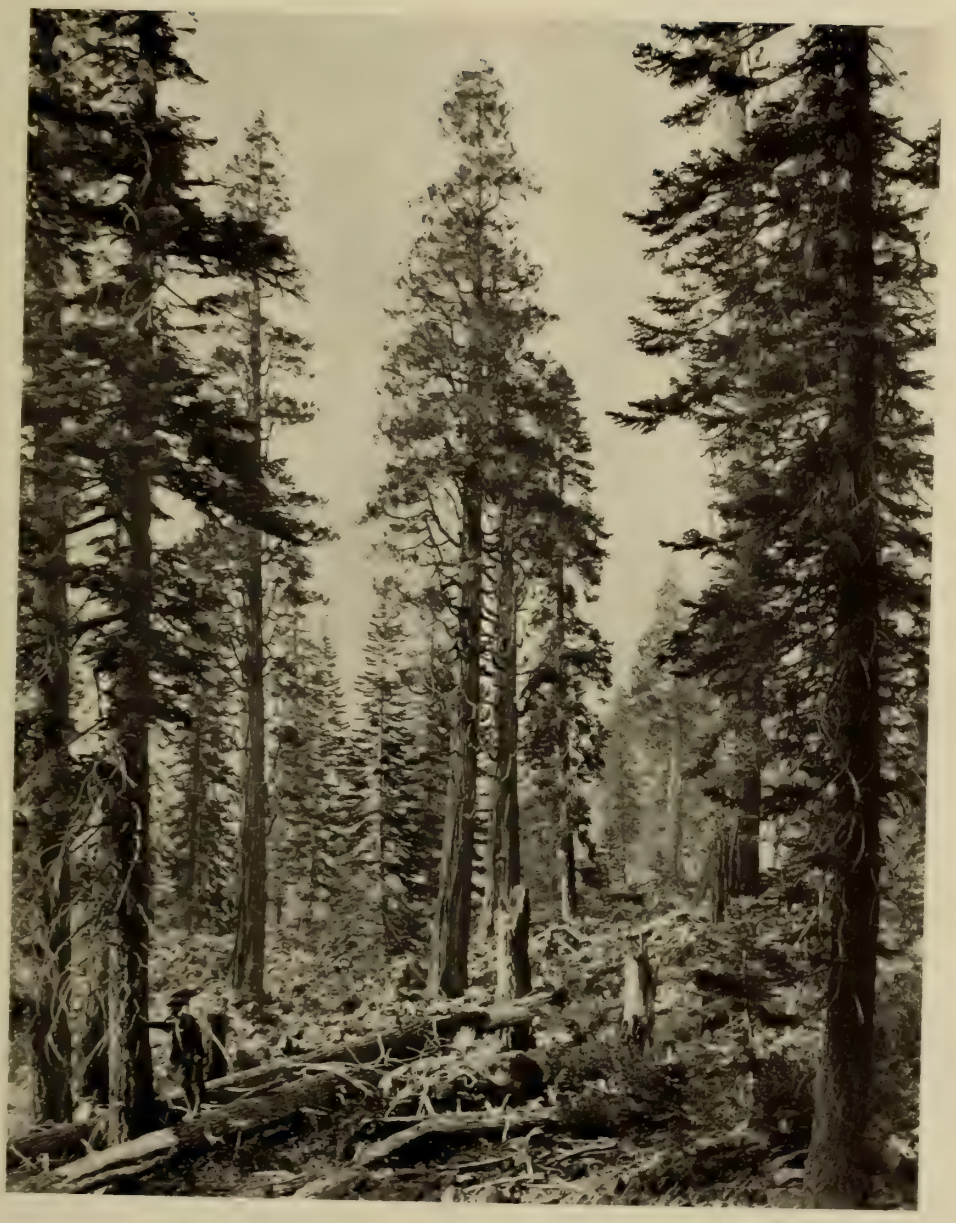

FIG. 22. IN THE PACIFIC FOREST

Virgin growth of Incense Cedar and Red Fir, Siskiyou County, California. (Incense Cedars in the centre, Red Firs at right and left). See colored transparency, Forestry Hall

broad; in maple, elm and ash they are moderately broad; in willow, they can be discovered only by means of a magnifying glass.

The presence of the pith rays proves descent from more primitive trees of much less strength of trunk, their bulk being made up of pith as are the stalks of corn of to-day. Pith rays are lines of weakness in the trunk; especially are they such in the lumber. Boards cut with the pith rays (radial or quartered) are, of course, less liable to warp and split than are those cut across them (tangential).

FORESTS, THE WEALTH AND THE NECESSITY OF THE NATION

ORIGINALLY the people of America possessed great forest wealth which they did not realize exhaustible, wholly ignorant of the country's growth in population and industries. To-day a timber famine is in sight, and there is still far too little realization that this forest wealth is exhaustible; we are destroying annually three and a half times as much wood as new growth adds. Unless all forests from this time on are managed according to some system which will no longer exhaust, but instead, will reconstruct, it is thought that twenty years will see the end of the timber supply in the United States. The original forests covered 850,000,000 acres; at present 550,000,000 acres[1] are forest lands but in large part the trees represented in these forests have only a fraction of the commercial value of those of the primeval forest. (See Figs. 21 and 22.)

An even more impressive view of the situation is given by the following figures, which are averages calculated for the five years previous to 1908, showing the ten countries that lead in the net wood exports and net wood imports respectively:

Countries Selling Wood	Tons	Countries Buying Wood	Tons
Russia with Finland	5,900,000	Great Britain and Ireland	9,290,000
Sweden	4,460,000	Germany	4,600,000
Austria-Hungary	3,670,000	France	1,230,000
Canada and Newfoundland	2,144,000	Belgium	1,020,000
Norway	1,040,000	Denmark	470,000
United States	1,020,000	Italy	420,000
Roumania	60,000	South America	330,000
India	55,000	Spain	210,000
West Coast of Africa	28,000	Egypt	200,000
West India, Mexico, Honduras, etc.	13,000	Holland	180,000

[1] The report of the State Commissioner for January 1, 1910, gives to New York State a holding of 1,841,523 acres of forested land, including 1,530,559 acres in the Adirondacks and 110,984 in the Catskills.

FIG. 23. A SILT BAR ON THE MISSISSIPPI RIVER

A deposit of the fertile constituents of surrounding land. This not only represents the barrenness of the land from which it came, but forms an obstruction to navigation, which must be removed by dredging

Thus it is seen that a large part of the world is getting its wood from Russia, Sweden, Austria-Hungary and Canada. The situation cannot endure, however, for these countries are destroying more forest than they are reproducing. What is in view therefore, is a world-wide wood famine.

Disastrous as a wood famine might prove to the industries of the country, it is not the only result attendant on the destruction of forests. The country faces problems of flood, drought and drying winds, of soils washed of their fertility, streams and harbors unnavigable because of irregular water-flow and because filled with tons of silt from soil erosion (Fig. 23), and all of these problems as well as questions of irrigation depend largely for their satisfactory solution on attention to the country's forests.

That they do thus depend lies in the fact that forests convert the region they occupy into a vast "sponge" for absorbing and holding water. It is said that the Croton Watershed controlling New York City's water supply needs at least 1,000,000 trees planted to husband the rainfall.[1] The

FIG. 24. THE ABSORBING POWER OF VARIOUS SOILS

Diagram to illustrate the relative amounts of water held by various kinds of soil and to show that leaf mould of the forest floor has greatest absorbing power

[1] One of the largest spring water companies in New York State has been reforesting its three hundred acres for several years to protect its springs and maintain the purity of the water and a regular supply. It reports planting 350,000 conifers consisting of larch, arbor vitæ, balsam, hemlock and various pines.

FIG. 25. MOUNT JEFFERSON, CASCADE NATIONAL FOREST, OREGON

The melting snows of mountains are absorbed and held by the surrounding forests as in a sponge, to be sent out slowly during spring and summer in an equalized supply to lower levels

FIG. 26. VIEW IN WINTER FROM MT. WILSON

If the forest is cut from foothills, their slopes, no longer protected by it and by a blanket of leaves and humus, must freeze solidly and remain frozen late; therefore, in spring, all the water in melting snow from the mountains flows over and down to lower levels without being absorbed,— wasted in damaging floods

FIG. 27. FARMING ON STEEP HILLSIDES

Scott's Creek, North Carolina. The lower slopes were cleared and cultivated till the soil was valueless; now the steep hillsides have been cleared and planted to corn. Soon all fertility will be washed out of the soil and the place will be abandoned. Forests instead of agricultural crops on steep slopes give continued returns while protecting adjoining lowlands from erosion and floods

' sponge" consists not only of the tree tops which form a close roof to keep out sun and wind, nor only of the layers of vines, brush, ferns, moss, dead leaves and humus on the ground (Fig. 24), but especially of the ground itself, which to a depth of many feet is a tangled interlacing of tree roots and of channels where formerly tree roots have been. Through such a forest sponge the water from winter snows and spring rains cannot penetrate rapidly but must gradually find its way to springs and brooks, producing a more or less equalized water supply to the surrounding region (Figs. 25 and 26). On the other hand, if the heads of watercourses are deprived of their forests, they allow the water to rush down the slopes, washing out the fertile constituents of the soil and producing floods in the lowlands,— a prodigality of water followed by lack in summer.

These facts are well illustrated in many places in the Appalachian region. Denuded slopes cleared for agriculture have yielded a profitable return for a few years; then decreasingly valuable because of the rapid eroding of the sloping fields, they served for pasturage a few years longer, then became wholly infertile (Fig. 27). This result in itself seems unfortunate enough, but consider the after-work of the rains that swept down these hillside farms (Fig. 28). It is said that in 1907 the floods from the onrush of one stream of this region (the Catawba River) caused a loss of a million and a half dollars' worth of farm buildings and stock.

Examine reports concerning the region of the Ohio Valley which, like the Appalachian region, possessed some of the finest broad-leaved woodlands of the country. Here farmers fought the forest for generations, regarding it wholly in the light of an enemy because the soil is fertile for agriculture. They cut the chestnuts, the walnut and hickory, the sycamore, elm and poplar, built log houses of the most perfect trees and burned the others. When demands for tanbark came they cut the oaks, sold the stripped bark and burned the logs in festival "log-rollings." At last they have produced a district well-nigh without woodlands, but at what cost! There are "mysteriously heaven-sent" blizzards and spring freshets; streams run almost dry in summer, and hot, drying winds scorch the crops; fruit-growing is continually more difficult. The price of timber has risen in unprecedented manner, while the tanbark supply is decreasing at such a rate, not only in the Ohio region but also throughout the country, that the total product in 1907 was 156,941 cords less than that of 1906.

Fortunately the damage to the nation's forests is not irreparable. Now that the country is known throughout its extent and careful estimates of its timber land have been made, now that the imperative necessity of forested uplands to control water supply is understood, there has come about a

FIG. 28. ONE OF THE DISASTROUS RESULTS OF A FRESHET

Sand deposited over alluvial bottomlands in Catawba County, North Carolina. This same flood caused the loss of a million dollars' worth of farm buildings and stock

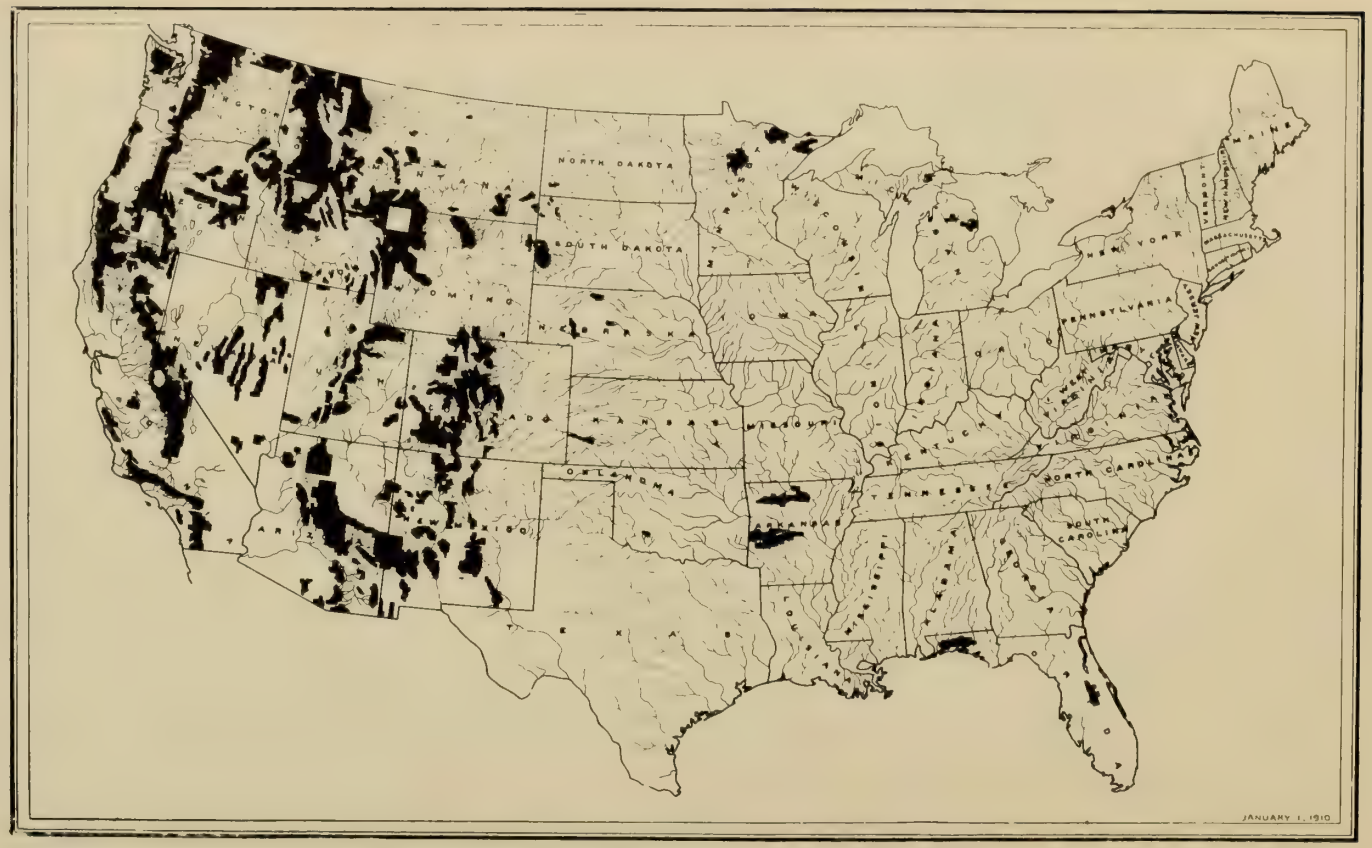

FIG 29. NATIONAL FOREST RESERVES, JANUARY 1, 1910

Before the close of 1910, these reserves reached an acreage of about 196,000,000. For facts concerning the eastern reserves in the White Mountains and Appalachians, see note p. 35

sentiment for united effort in two directions: (1) conservation of remaining forests so that they will be made to yield a product without exhaustion to themselves; (2) reforestation of the heads of watercourses.

CONSERVATION OF EXISTING FORESTS

A LONG step was taken toward the conservation of forests when an act of Congress of March 3, 1891, authorized the President of the United States to set aside from time to time pieces of woodland for the benefit of the American people. Such reserves (Fig. 2*a*), covering an aggregate of about 196,000,000 acres have been made by Presidents Cleveland, Harrison, McKinley, Roosevelt and Taft, and on February 1, 1905, the administration of these reserves was transferred to the United States Department of Agriculture, so that they are now under the care of experts in forestry. That the formation of national reserves is not a sufficient action, that the saving of the forests of the country still depends directly on individual and corporation owners rather than upon the nation, is seen by a comparison of acreage: the total extent of the reserves is one-third of the farm woodland of the country; it is insignificant when listed beside the millions upon millions of acres owned by railroads and by leaders in forest industries.

The work in conservation must be brought about by a coöperation that will result in legislation to bind the Nation, the States, all corporations and individuals. A move in the right direction was made when the Maine Supreme Court decided (March 10, 1908) that a state had the right to restrict the cutting of trees on private land, if the welfare of the general public was endangered by such cutting; also when Louisiana brought before the legislature a similar law, even more definite in its restrictions. By far the most important event in the movement in 1908 was the meeting of the Governors' Conference in May, followed by the joint Conservation Conference in December. Results cannot be obtained except through a union of the States;[1] the forests in Wyoming must be conserved to give

[1] The Weeks Bill:

> To enable any state to coöperate with any other state or states, or with the United States for the protection of the watersheds of navigable streams, and to appoint a commission for the acquisition of lands for the purpose of conserving the navigability of navigable rivers.

This bill, the product of the combined study of some of the ablest men in Congress, is a general conservation bill for the creation of national forests. The immediate interest, however, lies in the Appalachian and White Mountain regions controlling the watersheds of the most important rivers of the East and the South and containing a great part of the timber supply.

The question of reserves for the East has been under discussion for ten years. The Weeks Bill itself has previously passed the Senate three times and the House once. In the sixty-first Congress it again passed the House, June 24, 1910; it was filibustered in the Senate, however, so that Congress adjourned without a passage of the bill. The Weeks Bill is scheduled to come up for Senate vote on February 15, 1911.

FIG. 30. A TRAP FOR FIRE

Clean out dead brush and dead trees and put into a condition to withstand fire

water to the dry plains of Idaho; forests in Colorado equalize the water supply in Kansas; the success of the great irrigation project in Nevada depends on the extent and condition of forests in California. Changes that may come in the near future, wholly to transform the situation, to encourage tree planting and to protect our forests, concern technical points such as taxation of forested land and trade relations with foreign countries.

A question comes from forest owners, "Is the fact that a forest is an investment consistent with conservation?" In answer, experts hold that there are common-sense forestry methods which, if employed in the management of any given woodland, will allow a man to cut his timber now, yet save or grow a better crop for a later harvest; that the value of his investment is increased, for it yields almost the usual immediate profit and a greater deferred gain. That the deferred profit will be great is due in part of course, to the annually decreasing supply of timber and the increasing demand, the yearly consumption at present being more than three times the yearly forest growth. One lumber company estimates that if, when a long-leaf pine forest is cut, twenty per cent of the stand be left, this will yield nearly half the original cut in twenty years,—a two per cent investment if there be no increase in value of timber in the twenty years, a ten per cent investment with the probable rise in value. Many lumbermen who bought long-leaf forests at fifty cents per thousand feet believe that in twenty years these forests will have a value of ten dollars per thousand at least. Dr. C. A. Schenck, formerly forester of the 125,000-acre Biltmore estate in

North Carolina, is quoted as selling white oak at fifty cents per thousand board feet in 1896 and receiving offers of eight dollars per thousand in 1904.

The care and reconstruction which will mean large pecuniary profit to forest owners, varies in different parts of the country and also in different woodlands of the same region, depending on the kinds of trees present, the condition of the forest and the proximity to market. In many cases the advice of a trained forester should be obtained (see p. 67).

SOME FORESTRY METHODS

IF WE enter a tract of forest in the East we are likely to find closely-growing second growths, sometimes chestnut[1] but as often sassafras, ironwood, dogwood, gray birch, red maple and other species of rela-

FIG. 31. LODGEPOLE PINES, 20 TO 25 YEARS OLD

A young forest in need of thinning and cleaning. Bitter Root National Forest, Idaho

[1] Since 1905 great ravages have been made among chestnut trees by a blight or fungus *Diaporthe parasitica*. The forests of southern New England, of New York and New Jersey have suffered most, the estimate of loss being $10,000,000. So far the fungus yields its hold neither to known remedies nor to those newly tried and threatens to destroy all chestnut trees in the East.

tively small commercial value. There is little sign of the primeval growth of elm, hickory, hard maple, white oak, ash and white pine. Moreover many of these second growths are bent or broken, insect-infested, or burned and decaying at the base. The reforesting has been according to a wasteful and slow struggle for existence. It is possible that eventually the trees

FIG. 32. FOREST AT NEMO, SOUTH DAKOTA

Cut stumps low and obliquely to shed rain. This will do much toward ridding the forest of breeding places for insects.

Americans no longer cut off an entire crop of 100 to 200 years' growth with no care for future crops. The problem is to bring a forest to its fullest producing capacity

dominant in the original forest might creep in and displace these, but the result would be a matter of many years. To turn such woodlands into profitable investments is the problem of their owners. Yet scientific forestry to-day is reported in practice on only seventy per cent of publicly owned forests of the United States, and probably on less than one per cent of those privately owned.

Certain fundamental suggestions are applicable to woodlands of any kind or size in any part of the country.

1. Clean out dead brush and dead trees, utilizing this material before it is wholly wasted, and also leaving the forest in a condition better to withstand fire (Fig. 30). Cut out insect-infested trees.

FIG. 33. WASTE IN CUTTING

Material left for insect breeding places and for fire. Black Hills National Forest, South Dakota

FIG. 34. PREVENTABLE WASTE

Fire lessens the productive capacity of soil and may set back young growth for a century or more

2. At the same time thin the forest to let in light and air (Fig. 31); leave the most promising trees (some for seed trees); cut out undesirable species, old trees no longer growing, spreading trees that overtop others of value, and perhaps, trees that grow slowly or that never attain large size. Thin only to such an extent that the crowns of the remaining trees will meet in three or four years; if greater thinning is resorted to, reforest in the open spaces, if only to prevent growth of grass and shrubs and drying out of the humus.

3. Cut all stumps obliquely to shed rain, also as low as possible (Figs. 32 and 33). These precautions will do much toward ridding the forest of breeding places for insects. See p. 63 in regard to sprout growth from stumps.)

4. In cutting and removing trees avoid injury to the seedlings and young trees. This is one of the most difficult and imperative of forestry laws.

5. Protect from grazing and from fire (Figs. 34 o 37).

If used for grazing, a wood lot rapidly decreases in reproductive power, for cattle or sheep are certain to destroy the seeds and seedlings of the ground as well as the trees of a few years' growth. If the woodland occupies a hillside, animals do much injury by loosening the herbage that holds the soil in place.

Forest fires have increased in frequency and destructiveness till they

FIG. 35. BURNED AND WINDTHROWN TIMBER

A hint of the terrible fire havoc in the Bitter Root Mountains, Idaho, 1910

demand national attention. Each new one of large proportions proves a national calamity. Conservatively estimated, the loss to new forest growth amounts annually to $90,000,000, leaving out the $50,000,000 waste of mature timber as well as the loss due to decreased fertility of the forest floor.

FIG. 36. FIRE IN VIRGIN WHITE FIR

Prattville, California. The problem of insurance of forest property at rates no prohibitive must come up for settlement in the near future

In case of large and isolated tracts of land, forest rangers must be employed;[1] in smaller woodlands, fire lanes, constructed to divide the forest

[1] Systems of telephone lines connected with outlooks have been found to facilitate greatly the work of these rangers.

Secretary of Agriculture James R. Wilson has signed an agreement with the Great Northern Railway Company and with the Northern Pacific Railway Company by which in the future the Forest Service and the railroads will coöperate closely in preventing fires in national forests adjoining the tracks of these companies.

into small tracts, will prevent the spread of a fire to disastrous proportions; everywhere and at all times care must be taken to prevent the starting of forest fires from camp fires and burning brush.

The aim of all such work is the improvement of the woodland, although there may result a considerable product for home use and sale. Such improvement, made even at odd times by a farmer without help, has been known to increase the value of the wood lot forty per cent. When the aim of a given cutting is a large product for market, still the forest should be left in an improved, undepleted condition, the cutting accompanied by reforesting. For this cutting and attendant reforesting, few general laws can be made. The method most practicable is the so called "Selection Method" by which selected trees here and there are cut, the owner always keeping in mind the kind of forest he wishes to have after the crop is removed. He must consider the trees remaining as to age, condition, tolerance for shade and market value of species. Sprouts or seedlings from near seed trees will soon fill up the opened spaces; or better still, young trees raised in seed bed and nursery may be planted and so the species fully controlled. By this method a very irregular mixed forest results, with trees of many sizes and kinds, capable of yielding varied products (see p. 52). Trees tolerant of shade (beech, maple, spruce and hemlock) can be made to fill in below

FIG. 37. DISASTROUS RES ULTS OF FIRE

Although occurring twenty years ago, the fire has been followed by no young growth. Bighorn National Forest, Wyoming

those not shade-enduring, such as oak and hickory. The greatest difficulty in the management of a selection forest consists in not injuring young trees when getting out a crop.

If a forest consists of trees of relatively even size and age the "Strip" or the "Patch" method may be followed, in accordance with which one portion is cut clean each year. Of course, if a forest is to yield equalized annual incomes, it must consist eventually of as many sections, varying in ages from seedlings to the marketable size, as it requires years for the trees to attain marketable size. For instance, to yield annual crops of box-boards cut from white pine trees of thirty-five years' growth, a forest must consist of thirty-five sections; to gain annual crops of railway ties produced from catalpa trees fifteen years old, the plantation must have fifteen sections.

AIM OF WOOD LOT OR FOREST

THE aim of the wood lot or forest will be determined on (1) its conditions as to species and soil and (2) on the present and probable future market.

Soft Woods in Proximity to Pulp Mills

It is fortunate if a forest of soft woods (balsam, hemlock, spruce, Carolina poplar, aspen, cottonwood, willow, basswood, or tulip-tree) has a near market in the shape of a pulp mill. In 1907 there were used in the United States for the manufacture of paper pulp, 3,962,660 cords of wood, more by 300,000 cords than in 1906. Of this amount 2,700,000 was spruce wood, one-third of which came from Canada.

Trees for the pulp industry must be grown close together so that the trunks will be clear of branches, because first-grade pulp wood, which may bring as high as $10 per cord, is free from knots. Since a pulp mill uses very small pieces, even as small as 2 ft. by 4 in., much of the material taken out in thinning a woodland may be sold to advantage. Experiments in the future may prove that paper can be made from still cheaper material than wood, perhaps from annual plants of rapid growth, cornstalks or the stems of other tall grasses. Here, as in all questions of agriculture and forestry, landowners must study the markets.

In the case of pulpwood, it is especially true that conservation means not only maintaining a supply of raw material but also operating economically in the use of this supply. Timber waste must be used as pulpwood, clear logs sent to the sawmill and slabs, tops and imperfect trunks turned into pulp. This economy is forced upon us, particularly since Canada to protect

her own resources prohibited the exportation of unmanufactured wood (May 1, 1910).

Durable Woods, and Market for Posts

If conditions combine a market for posts and a woodland of durable woods such as cedar, white oak, Osage orange, catalpa, black locust, chestnut or mulberry, cypress or redwood (see p. 47 for treated woods serviceable for posts) the production of posts may be the aim, with reforesting by the sprout method (see p. 63) to gain rapid growth and frequent crops. It is the heartwood only that makes a durable post, so trees must be allowed to attain a diameter that will give a preponderance of heartwood, and naturally the best trees for the purpose are those in which the formation of heartwood follows rapidly on the growth of sapwood (see Fig. 6, p. 13). Reports from Ohio recommend honey locust for posts; if grown close in a good soil, it is said to produce straight, smooth posts more durable than even cedar or white oak.

Durable Woods, and Market for Ties, Poles or Piling

The cutting of durable woods may be deferred until the trees attain a size suitable for railway ties (trees 12 to 16 inches in diameter; also the upper logs of larger trees). About sixty per cent of all ties in use at present are white oak, but the white oak supply is now practically exhausted. In the Lake States hemlock and tamarack are being used. Chestnut sprouts reach size for railway ties in thirty-five years. Every mile of railroad requires 2500 ties and if these ties must be replaced every seven years, as previously, the demand means cutting clear one-half million acres of forest annually. It is reported that the Pennsylvania Railroad uses 620,000,000 ties in its system. This corporation has begun planting trees for production of its own ties: 3,482,186 trees have been set out; 290,000 seedlings were imported in 1908. More than 1,000,000 trees were planted along the railroad's right of way in 1909. The species are black locust, red oak and catalpa, also various conifers such as Scotch pine, white pine and Norway spruce. (See wood preservation, p. 47.)

If durable woods are allowed to grow until they cut logs 25 to 30 feet long (upper diameter 5 inches or more), they find sale as telegraph or telephone poles with a market value of from two to ten dollars per pole.

Chestnut poles may be grown in 42 years from sprouts and will give 12 years' service. Red cedar, which combines more valuable qualities for poles than any other wood, must pass out of use with the present supply since the posts are cut from trees 90 years old and last only about 15 years. Arborvitæ also is one of the most desirable timbers for poles but, like cedar, can be depended on only till exhaustion of the present supply since the tree is

FIG. 38. "OPEN-TANK METHOD" IN WOOD PRESERVATION

Experiments have proved that treatment of wood in a preservative fluid (coal-tar creosote) makes it resist decay in moist situations. This fact will revolutionize the market for posts, poles and railway ties

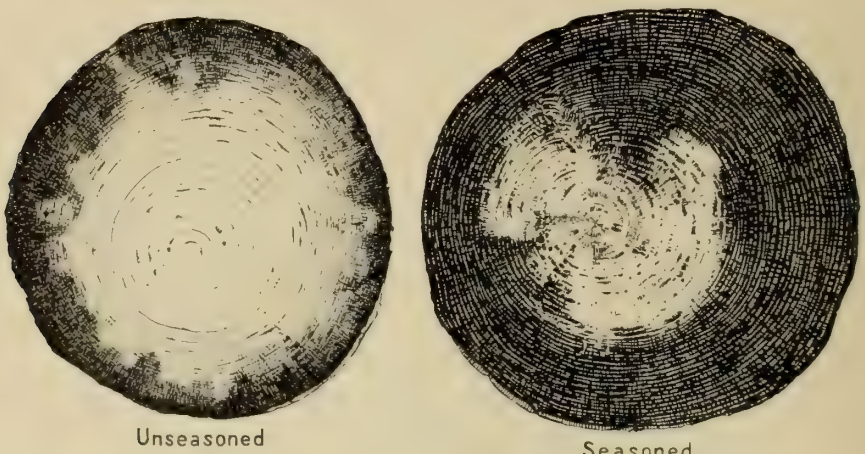

FIG. 39. COMPARATIVE SATURATION IN UNSEASONED AND SEASONED POLES

A partial vacuum must be created in the wood before the preservative fluid can be forced in; and since air can be expelled much more readily than water, seasoned timber is more effectively treated than green

extremely slow in growth. For piling, long-leaf, short-leaf and loblolly pine, white and red oak are used on the Atlantic Coast and the Gulf of Mexico, while Douglas fir supplies the demand in the Pacific region.

Under the waning supply of durable woods, experiments have been in progress which prove that the power of posts, ties, poles, mine and wharf timbers to resist decay in moist situations may be greatly enhanced by treatment in a preservative fluid. So successful has been the work that it is likely to revolutionize the market as regards these products. By treatment, not only do the durable woods gain a lengthened period of service but also less durable woods may be made to take the place of durable woods. The United States Forest Service states the following concerning fence posts: "Resistance of all treated posts to decay is alike, regardless of kind of wood used; posts with much sapwood take a deeper impregnation of the preservative." This means that the cheapest, least durable woods, like poplars, will come into service for posts, leaving the durable woods for use in interior finish and cabinetwork. According to the open-tank method of t eatment (Fig. 38), formerly given the highest recommendation by the United States Forest Service, the wood is kept immersed in coal-tar creosote for a number of hours, depending on the kind of wood, and is then plunged into cold creosote, or is left in the cooling preservative over night. The wood should have been previously seasoned (Fig. 39) and its sapwood should be saturated with the oil. Brush treatment, by which the wood is painted with hot creosote, is less expensive, but also less effective because of the slight penetration by the oil (Fig. 40). Treatment in closed cylinders under pressure, is considered the best method as far as results are concerned, but it is five times as expensive as the tank method.

The effectiveness of the tank treatment lies in two facts, namely, (1) creosote oil protects the wood from the entrance of water and (2) creosote — being antiseptic — protects the wood from the attacks of bacteria and various fungi which grow rapidly in damp situations and whose growth means decay of the wood. The theory that insures the impregnation of the wood by tank process is as follows: heating in the creosote expands the air contained in the wood until much of it is driven out; plunging the wood into cold preservative causes the air left to contract leaving a partial vacuum which is filled at once by the cold oil forced in by atmospheric pressure (also by capillarity).[1]

Treatment of wharf timbers with creosote protects absolutely from marine borers (Fig. 41). Zinc chloride is used to some extent in treatment of woods but the resulting protection is not permanent because the preservative is soluble in water.

[1] The importation of 25,000,000 gallons of creosote into New York City in 1908 was an increase of 21,500,000 gallons over that of 1904. This indicates great development of wood preservation.

FIG. 40. BRUSH METHOD OF TREATMENT

Cheaper but far less effective than a saturation method

FIG. 41. DESTRUCTION BY MARINE BORERS

Piles at Norfolk, Virginia. Treatment of wharf timbers with creosote protects absolutely from such attacks

FIG. 42. BLACK WALNUT (*Juglans nigra*) 49

New England to Florida, Michigan to Texas. Wood hard, susceptible of a high polish, prized for cabinet work and interior finish. Forestry hall, Case G, 7–8

50 FIG. 43. VALUATION SURVEY AT WASHINGTON, D. C.

Foresters can estimate not only the amount of saw timber in a forest but also the posts, ties, poles and firewood over and above this timber. Conservation means utilization of the whole tree

FIG 44. GUMPICKER'S CAMP

Spruce woods near Barneveld, N. Y. Gum gathered from the trunks of spruce trees is a paying by-product of the northern forest

FIG. 45 SUGAR MAPLES AT BURLINGTON, VERMONT

Maple trees may be tapped for maple sugar and still yield good timber.

Hardwoods and Cooperage

White oak and elms have been the standards for cooperage work which, like tanbark, entails great waste of material. Coopers have been forced into using beech, red oak, maple, ash and birch, especially for slack cooperage (barrels for dry materials). Logs grown for cooperage should be more than ten inches in diameter. Their market prices are unusually good.

Beech, Maple, Birch, and Acid Factories

In certain eastern districts acid factories demand large supplies of wood for distillation, preferably of beech, maple and birch (8000 cords per year). Some of the products of these factories are wood vinegar used in dye works; wood alcohol of special value in chemical works; acetic acid utilized as vinegar; and charcoal.

A Timber Forest and its Varied Products

If a woodland consists, or can be made to consist in the future, of valuable trees grown for timber from the seed, the owner can well make his aim the production of saw logs for quartered and other high-priced lumber which will find ready sale in home or foreign market. A timber forest may have a wood capital twenty-five times as large as that of a sprout forest. Some of the most valuable timber trees are black walnut (Fig. 42), black cherry, white oak, white ash, hickory, red oak and sugar maple. In a timber forest the distance of trees from one another is an important item: if too far apart, the trunks do not clear well and the lumber is knotty; if too close together, the trunks remain too small in diameter.[1]

A timber forest may yield many products besides high grade lumber.[2] A forester can estimate not only the saw timber in the trees to be cut but the number of posts, ties, poles and firewood over and above this timber (Fig. 43). More and more the entire timber is being used, proving one of the most effective methods of conservation. This complete utilization has been made possible by the establishment in many localities of charcoal

[1] See "Rules and Regulations for the Grading of Lumber," Bulletin 71, Forest Service, U. S. Dept. of Agriculture

[2] The following figures are of interest:

The United States uses annually 100,000,000 cords of firewood
40,000,000,000 feet of lumber
1,000,000,000 posts and poles
118,000,000 railroad ties
1,500,000,000 staves
133,000,000 sets of heading
500,000,000 barrel hoops
3,000,000 cords of native pulp wood
165,000,000 feet of mine timbers
1,250,000 cords of wood for distillation

FIG. 46. TURPENTINE FOREST OCILLA, GEORGIA 53

Long-leaf pine trees, if properly managed, may yield a turpentine product and have their timber value remain unimpaired. The Naval Stores industry of the United States in 1908 put out 36,500,000 gallons of turpentine and 4,000,000 barrels of rosin at a combined value of $32,000,000

blast furnaces and chemical plants to convert bark, limbs, edgings (Fig. 12) and even sawdust into some valuable product. If near a spool factory, birchlands may be profitable. Excelsior may be a paying product of mixed woodlands; the United States uses annually for excelsior 60,000,000 feet of timber (about 10,000 acres of forest). Each winter there is a large market for Christmas trees, especially near cities. Dealers estimate that New York City annually handles 125 carloads of Christmas trees, each carload containing 2000 trees. Large numbers of these come from the Adirondacks and from Canada. Gum picking may bring a considerable sum to dwellers near spruce forests (Fig. 44). The maple sugar and turpentine industries market "by-products" of a woodland without injuring its timber value, provided in the latter case that the trees are cut before injury comes to the chipped trees from insects or fungi (Figs. 45 and 46).

WORK OF FORESTATION

FORESTRY is of economic interest to landowners throughout the country, but planting trees in largest numbers must lie with the western farmer on prairie or newly-irrigated land. Each farm there, as well as in the East, should have its wood lot. In installing tree plantations in these regions, not only must fast-growing trees be chosen but also the young trees must be protected in nurseries until strong enough to endure exposure and until possessing top enough to shade the ground, for in summer the soil becomes dry. Greatest success has come in raising hardy catalpa trees (Fig. 47). A famous experiment with this tree was made on the Yaggy plantation in Reno County. The trees were grown from seeds and the seedlings were transplanted when one year old between rows of corn to the permanent site. One hundred and twenty acres were planted in 1890, eighty acres in 1891, two hundred and forty acres in 1892. Ten years' growth realized a net gain of $197.55 per acre, which amount will be greatly increased by a few years' delay in harvesting. Hardy catalpa is a species with known values in the present market, i. e. trees six years old produce posts valued at ten cents each; trees fifteen years old make ties worth fifty cents each, and two or more posts besides; trees twenty-five years old can be cut for telegraph poles which may realize fifty dollars each.

Tree planting is advisable as follows:

(1). In the forest where gaps made in thinning or in removing a crop

FIG. 47. PLANTED HARDY CATALPA, KANSAS 55

Catalpa attains size for posts in 8 to 10 years, for telegraph poles in 20 to 30 years. See p 54

are so large that the crowns of the remaining trees will not meet and shade the ground within a short time.

(2). On rocky land with thin soil little valuable for agriculture.

(3). In wet places where no other crops will grow (Fig. 48).

(4). On hillsides too steep to plow (Fig. 45) especially if these slopes adjoin fertile fields and are subject to washing (Fig. 5). If a forest in such

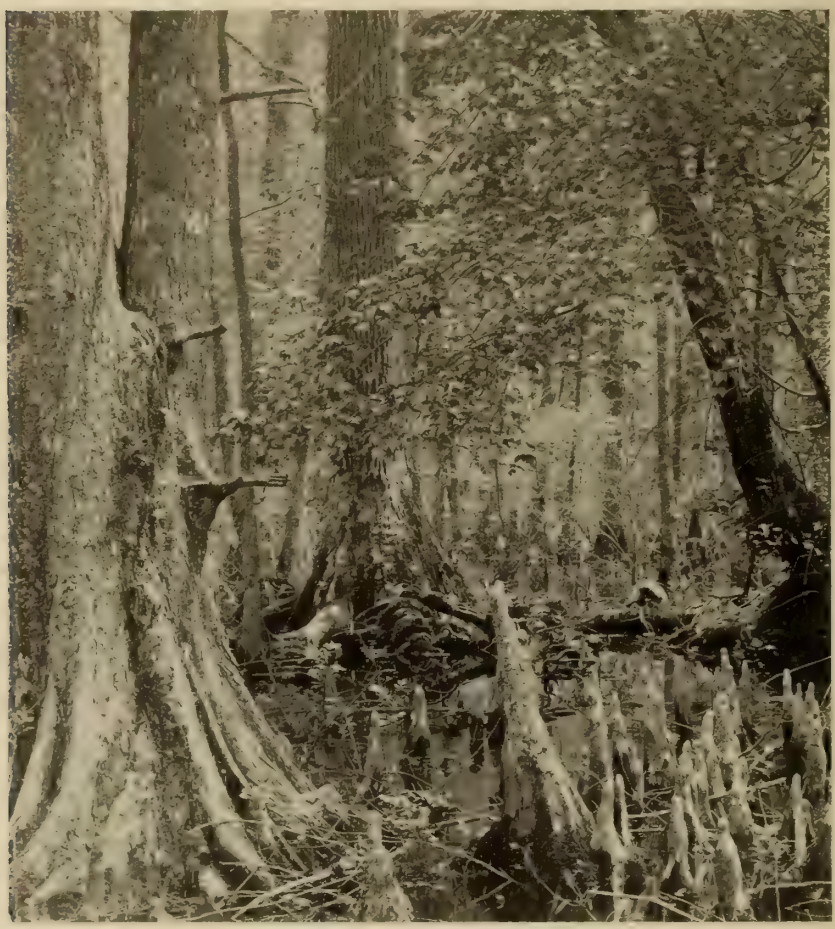

FIG. 48. DISMAL SWAMP, SHOWING "CYPRESS KNEES"

The rich soil of swamp lands supports luxuriant growth. Giant cypress trees have been known to measure 40 feet in circumference.

A problem of the immediate future: to drain swamp lands north and south, plant forests, and incidentally better health conditions

FIG 49. SEED PLANTERS, ANGELES NATIONAL FOREST, CALIFORNIA

Trees should be planted on hillsides too steep to plow, in the East or in the West.

a situation is to serve a double purpose, namely, furnish a tree crop for market and protect agricultural land, it is best to plant nursery-grown stock to control the species and hasten the reforesting.

(5) Along sandy shores, or along mud banks of rivers and creeks. Such forestation is imperative when the watercourses run through fertile soil which washes away during fall and spring freshets.

In addition to a wood lot there should be shelter belts of trees to protect buildings, crops or stock feeding-grounds from prevailing winds. It is advised that not less than one-eighth of a farm consist of woodland. Along the exposed sides of a wood lot encourage the growth of a dense border of shrubs and low trees to protect the woodland from drying and to prevent windfalls. If a forest border is to be planted, choose a rapid-growing species, such as box elder, hardy catalpa or Carolina poplar, and one or more slow-growing species for later and permanent protection, such as any of the conifers.

No tree crop in the East is likely to prove more profitable than white pine, in the wood lot, on sandy shores, hilly fields or worn-out land. White pine reaches marketable size in thirty-five years, i. e. growing close (6 to 9 feet apart each way) and unpruned for box-boards. A tract of pine for high-grade timber should remain uncut for a somewhat longer period. Such a tract will increase its value greatly, even fifty per cent, if the trees

FIG. 50. EFFECTS OF EROSION, CATAWBA COUNTY, SOUTH CAROLINA

Trees should be planted on sandy slopes that lead down to fertile fields. Such trees will furnish a tree crop as well as protect the fields from erosion

FIG 51. KNOCKING SEEDS OUT OF PINE CONES

Cleveland National Forest, California

are kept thinned and pruned. Such a cared-for tract may yield 25,000 B. M. per acre, five times the average yield of Michigan white pine forests.

The following figures are interesting for owners of New England abandoned farms:

Average cost per acre of land		$4.00
Average cost of raising and planting seedling white pines		4.84
Average taxes at 2 per cent for 40 yrs.		3.20
		$12.04
Compound interest for 40 yrs. making total cost		$50.99 per acre.
Average yield per acre box-board timber, 40 cords, at $4 per cord	$160	
Net profit	$109.01 per acre.	

GROWTH OF TREES FROM SEEDS

TREES in nature grow not only from seeds but also from stump sprouts and sometimes from cuttings (twigs broken from the trees during storms). Man's best method, with few exceptions (see p. 62) is to grow trees from seeds.

Obtaining the Seeds

Seeds may be purchased from nurserymen but the grade is not always reliable and the cost is high. If possible, collect the seeds for the immediate need. Collect thoroughly ripe seeds from well-grown roadside or field trees or from trees at the edge of the forest, remembering that as a rule the best and largest seeds produce the best trees. If seeds are obtained from a distance, the resulting trees will be hardier if the seeds come from a more northerly rather than from a more southerly section. Test the seeds by cutting open a few to see that the kernels are plump and moist. If desired make an absolute test as follows: plant some of the seeds in sphagnum or wet sand; cover the seeds their own depth and keep moist; the greater number of tree seeds germinate in from ten to thirty days.

Disposition of Tree Seeds for the Winter

Nature plants tree seeds soon after they ripen; the time of sprouting is another matter. Seeds that ripen in the spring are likely to sprout and make strong seedlings before winter; such are the elms and soft maples, poplars and willows. Of those that ripen in the fall, a few such as the white oak may grow before frost, but the larger number wait until spring. Among those that lie dormant one or more years are the linden, locust and red cedar.

Seeds should be removed from their cones, husks or pulpy coverings (Fig. 51) and then spread out to dry in the sun or in a warm room of the house. Dry only enough to prevent moulding; excessive drying destroys the vitality of the seeds. To insure for the winter the safe keeping of nuts and acorns and the smaller seeds, except those of conifers, arrange in a box in layers separated by layers of moist sand. Store this box in some cool cellar-like place or bury it in a shallow pit out of doors, heaping the soil above and further protecting from rain by boards. Seeds of pine, spruce and other conifers may be kept in boxes of dry sand, or in bags hung in a dry, cold place.

If a seed bed can be made in the fall, many seeds may be planted advantageously at that time. The loam of the ordinary garden bed serves well for broadleaf trees; conifers need a mixture of loam and one-third sand. The

seed bed should be spaded deeply and well fertilized with forest mould, phosphate of lime or well-rotted manure. Locate the seed bed on the north side of some building, fence or hedge so that it will be sheltered from too great sun. The seeds may be sown very thickly in drills 8 to 10 inches apart. Cover them about twice their own depth; seeds are often killed by deep planting. Cover the seed bed with a two-inch layer of chaff or of sphagnum or pine needles to keep the soil from drying. Before frost comes give the bed a thick protecting cover of hay or straw.

Spring Planting of Tree Seeds

If the seeds kept through the winter are to be planted in an out-of-door seed bed they should not be removed from their winter quarters until time for that out-of-door planting after the frost is out of the ground; but if they are to be started in flower pots or boxes in the house, they may be brought out and planted in February or March. They must be planted immediately on being disturbed. The surface of the earth in the flower pots or boxes should be kept moist by a layer of sphagnum or chaff, of crushed dead leaves or of pine needles.

Most tree seeds are slow in germination, beech, maple and oak requiring

FIG. 52. COVER FOR SEED BEDS

In some instances, the cover is placed high enough to make a lath house in which those in charge can work, although a low cover is much to be preferred. Salt Lake National Forest, Utah

six weeks to appear above the ground, pine and spruce four weeks. Growth may be hastened by soaking the seeds twenty-four hours before planting. Seeds of linden and locust should have boiling water poured over them or should be soaked in hot water for three or four days.

How to Care for Seedling Trees

As a rule seedling trees grow very slowly their first year. Pines grow three inches or less, in fact, pines grow very slowly for the first five years and not rapidly until they are ten years old. Broadleaf seedlings grow faster than those of conifers; chestnut and a few others make the astonishing growth of fifteen to twenty-four inches their first year.

Seedlings grown in the house need the ordinary care given to house plants. If they are grown in the seed bed they must be kept partly shaded, and be protected from wind. It is suggested that a bed have a cover made of strips of lath, the width of a lath apart. This cover should be placed one foot or more above the bed, held on stakes driven into the ground at the corners of the bed (Fig. 52). A cover similar to this may be made of brush. Any cover should be movable so that it can be taken off on dark days. Conifers should be shaded for two or three years; broadleaf trees only during their first season.

Keep the soil of the seed bed loosened; also free from weeds. Thin the seedlings so that each will have light and air. For winter protection the row of seedlings should be banked with earth and the nursery bed covered with straw. For directions for transplanting see p. 64.

GROWTH OF TREES FROM CUTTINGS

WILLOWS and poplars may be grown from cuttings. Thus a quick method is provided for covering land to hold the soil along streams (cottonwood is recommended for irrigation ditches), and to prevent severe erosion from overflow.

The cuttings may be put into their permanent place at once or may be started in a nursery bed or in boxes. Considerable moisture is needed until the roots are formed. The usual cuttings are one foot in length and one-fourth to three-fourths of an inch in diameter. Plant with the buds pointing upward, and place three-fourths or more of the cutting underground. The soil must be closely packed above each cutting.

Good results are gained by making the cuttings in late fall and keeping them buried in sand in the cellar or in some out-of-door place till spring, then planting as described. This is like the natural method; that is, the winter winds may whip twigs from willow trees, these twigs may lie dor-

mant, only healing the broken place, and grow in spring, increasing the number of willows along river or swamp.

In the practical work of growing willows for basketry — a paying venture in the meadows and bottomlands of agricultural districts — cuttings are started in beds or boxes in the fall and transplanted in the spring. The farmer plows a long furrow, lays the cuttings in the furrow, then plows a second furrow to close the first; makes a third for cuttings, a fourth to close it, and so on, putting some 34,000 or more cuttings to the acre. (For details concerning willow growing and its financial returns see Bulletins 19 and 46, U. S. Forest Service; also Circular 148.)

GROWTH OF TREES FROM SPROUTS

BROADLEAF trees, in distinction from conifers, have the inherent tendency when cut down to sprout from the stump, that is, to form new buds in the cambium. As we should expect, this sprout growth is unusually rapid at first, fed by the perfected root system of the original tree; and trees possessing the sprouting power in large degree have great economic value. A forest of basswood, catalpa, chestnut, blue gum, black locust, soft maple, Russian mulberry, Osage orange or white willow

FIG. 53. PLANTATION OF BLACK LOCUST

This species is valuable since it thrives in plantations and has an extensive range. See p. 64

can be perpetuated for many succeeding crops of posts or poles, fuel, or small timber without renewal from seeds, but the sprouting power diminishes gradually with age.

To insure good sprout growth, the trees should be cut in winter or early spring and should be cut low. The stump must be as nearly level with the forest floor as possible so that it will be protected by a cover of leaves and snow and so that the sprouts may early form their own root systems. If the stump is a foot or more high, the cut surface should be oblique in order to shed the rain. All of the sprouts except three or four of the stronger ones should be removed at the close of the first season to give space and light for those remaining.

For hedges and windbreaks, Osage orange sprout trees are recommended. For production of fence posts in sprout forest, chestnut, hardy catalpa (Fig. 47), black locust (Fig 53) Russian mulberry and Osage orange are valuable. If the purpose of a wood lot is the production of posts, poles or ties, the sprout method is used even at the beginning; that is, at the close of the second year after the seedlings are in their permanent sites, they are cut back to the ground, then at the end of the next year all but one sprout is cut away; thus is gained a taller, straighter shaft than the seedling would have given. During the succeeding years these shafts are kept well pruned of low branches.

TREE AND SHRUB TRANSPLANTING

CHOOSE trees that are not too large and that are free from fungi and insects. The various maples and the American elm transplant easily and may be eight to ten feet high; but almost any forest tree can be safely transplanted if only three or four feet in height. Choose trees suitable to the given purpose as well as to the selected place, — lawn, school grounds, roadside, windbreak, or denuded forest. Have in mind, however, that any tree or set of trees may serve secondary purposes, i. e. the trees of a windbreak may eventually produce good timber or telegraph poles; trees valuable for the roadside may also produce nuts or valuable tree seeds, or may have flowers that yield large amounts of honey.

It will pay to transplant wild seedlings to a nursery bed, strengthen them there for one or more years, then transplant to a permanent site. They must be transplanted as carefully as the older trees and must be shaded at first, as are nursery-grown seedlings.

It is thought that the transplanting of certain trees, especially of oaks and conifers, is made more liable to failure by an interdependence that

exists between the trees' roots and minute fungi of the soil (Mycorrhiza). When a tree is transplanted, these fungi are largely left behind and are likely to be lacking in the new soil.

Time of Transplanting

Transplant on wet or cloudy days in spring, or in warm regions in fall, when the tree is without its leaves and before the buds have opened. As soon as the buds open, it is too late to transplant with best success, since the new leaves will very likely die and the loss may not be replaced quickly enough to save the tree.

In the case of evergreen trees, theoretically any season will serve for transplanting, since they never lose all of their leaves. Practically, however, the best time is spring, when the buds for the new year's growth have not opened and the soil is not frozen. Summer cannot be the best time, since evaporation from the leaves under the summer sun must be so rapid that the tree may be injured before the roots are properly at work (see below, for ball planting of evergreens).

Method of Transplanting

The secret of successful transplanting lies in removing the tree from the ground with roots as nearly unbroken as possible, and in *keeping these roots from drying.* Do not expose the roots to sunlight or wind even for a few seconds; cover them — and keep them covered till they are in the ground again — with wet sphagnum or wet cloths, or best of all put them at once into a pail or tub of thin mud. Small trees may be carried in a pail of mud from the woods to the planting site.

If desired, ball-planting may be practised, that is the roots may be removed in a mass or block of earth. Conifers are difficult to transplant, in that they never revive if there is any drying of the roots, therefore ball-planting is recommended for them. This is often accomplished in winter, in which case the transplanting is begun at the approach of freezing weather, the hole for the tree is dug in the permanent site and the removal of the tree started. The digging about the tree is done a little at a time to allow deeper freezing of the soil about the roots; the tree is not removed to the new site until all of the soil is frozen even at the bottom of the block.

The hole for a tree should be dug wide enough to take the roots spread out in their natural position, and deep enough to let the tree settle into the soil to a position similar to that it had before transplanting. The soil to be put back into the hole must be made free from lumps and stones, so fine that it can be sifted about the roots. There must remain no air spaces, where rootlets may die because they cannot reach food. If the soil

is not good growing soil, it should be enriched by the admixture of well-rotted manure.

Hold the tree perpendicularly in position and sift fine soil over and around the roots till they are covered, slightly lifting and lowering the tree in its place to allow the particles of soil to settle close under and about the rootlets. After this, fill the hole with shovelfuls of soil, treading it down firmly as it is put in. Fill to a little higher than the surrounding level to allow for settling. Use no water during the transplanting unless the ground is very dry, in which case, put water on by sprinkling or spraying after the soil is well packed about the roots.

Trim the top of the tree so that it will not greatly exceed the extent of the root system, which probably was reduced in the transplanting. This cutting away of branches is especially necessary if the transplanting is done late in spring when the tree is in leaf, for the evaporating surface must be reduced. It is best for both the latter reason and for relation to the root system that evergreens be cut back whenever transplanted.

Almost any young shrub one to three feet tall, depending on the kind, can be successfully transplanted if care is used to keep the roots moist. Nothing could be more satisfactory for massed effects at the sides of the home lawn or for the school grounds, than the wild shrubs from the roadside or the woods border. Such shrubs are laurel, witchhazel, elderberry, spice-bush, sumach, flowering dogwood, red osier, maple-leaved viburnum, thorn apple, barberry and many others.

In planting a mass of shrubs follow directions for tree transplanting except that the whole space must be dug up so as to set the shrubs two to three feet apart. Do not leave sod between the shrubs or allow grass to grow there later.

Transplanting Stock from the Nursery

A tree nursery needs the same situation, soil and preparation as a seed bed (see p. 60). If the soil is dry, wet thoroughly the day before the transplanting. For hand cultivation, plant in parallel rows 2 feet apart; for horse cultivation, the rows may be $3\frac{1}{2}$ to 4 feet apart. Dig the trenches such depth as to allow transplanted seedlings to stand 1 to 2 inches deeper than they grew. Set conifer seedlings 4 inches apart in the rows, broadleaf seedlings 6 inches apart.

The important item here, as in all transplanting, is to avoid exposure of the roots to air for even a few seconds. As soon as the seedlings are out of the soil they should have moist earth, wet cloths or chaff thrown over them, or should be put into a pail or tub of thin mud. Leave plants in the nursery until 12 to 18 inches high.

Transplanting seedlings one or more times, from seed bed to nursery, from nursery to permanent site, strengthens the root systems by making

them more compact, and the resulting young trees are more vigorous than those left undisturbed. The long tap roots of oaks and walnuts and of catalpa should be cut off at the first transplanting. Older plants in the nursery should have root pruning some time before the last transplanting, that is, a sharp spade should be thrust into the soil around and under the trees.

PLANTING GUIDE

Compiled from the reports of the United States Forest Service

REFER to the Jesup Collection of woods for facts concerning the character of the wood and the economic value of each species with its associate trees; also for maps showing natural range. It was the original aim of Mr. Jesup that architects, cabinet makers and others interested in wood, as well as those interested in growing trees as a commercial venture, might have a ready place of reference for getting acquainted with not only the well-known species of American trees but also the many others little known and appreciated in the lumber market.

A forester can tell the rate of growth of various trees and therefore can estimate the time that it will take a given species to reach merchantable size and the average product that it will yield per acre. He can foretell, as a result, whether a particular woodland will or will not give satisfactory returns under the existing conditions of taxation and with the possibilities of fire. The United States Forest Service advises free of charge any applicant with a problem for economic tree planting. Foresters study the conditions of the locality and give particulars concerning species to be planted, how to obtain the young trees and how to plant them and care for them. If the application comes from some region not previously studied by the Forest Service, it may send agents to examine the locality and prepare planting plans. In certain cases, this direct examination may be made free of cost even for large commercial undertakings, provided the work is of considerable experimental and educational value. (See Circular 22, United States Forest Service.)

The Australian eucalyptus is proving a valuable discovery for America. Forestry experts are studying the problem of its successful culture both in the Southwest and in Florida. Eucalyptus has unusual rapidity of development coupled with an all-round usefulness of wood, and under the right climatic conditions is likely to give commercial crops in a much shorter period than our native trees. More than 23,000 acres in California have been turned over to eucalyptus growing during 1909 and 1910.

Many of the trees in the following list are those about which the United States Forest Service has gained definite planting data through actual experience and which have been proved to give best results under artificial conditions.

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Green Ash (*Fraxinus lanceolata*) CASE F, 10	Wood hard, strong, coarse-grained, somewhat inferior to white ash but often substituted for it. Used for agricultural implements, furniture and vehicles, posts and fuel. One of the most useful trees for windbreak or ornament.	Recommended for economic planting in the eastern half of the United States, also on the northern prairies and the semiarid plains east of the Rocky Mts., and on all irrigated western lands. Will thrive under adverse conditions, growing on dry sandy loam or stiff clay upland.	Nursery culture necessary. Transplant 1 year old seedlings (6–10 in. high) to permanent site. (Nurserymen's price $2 to $3. per thousand for seedlings). Cultivate till ground shaded. Pruning will increase value. Growth relatively slow. Post size attained in about 15 years. Height at maturity 60 ft., diameter 24 in.	Endures shade only moderately. Recommended for pure stands, spacing 4 by 4 ft.; or combined with box elder, hackberry, white elm, Scotch pine or red cedar (spacing 6 by 6 ft.) If planted pure, may be given an understory of wild plum, chokecherry or other shade-enduring low trees to keep out grass and weeds.	The more valuable white ash is to be preferred in moist regions. On abandoned timber claims in arid parts of Nebraska green ash has survived where nearly all other species failed.
White Ash (*Fraxinus americana*) CASE F, 11	Wood of great value; tough, elastic, fairly durable in contact with the soil, takes good polish and seasons without injury. Used as first-rank timber for furniture, interior finish, cars and vehicles, tools and agricultural implements. Good for fence posts. Favorite for ornamental planting.	Newfoundland to northern Florida west to Ontario and Texas. Recommended especially for the Ohio Valley, the region of the Great Lakes, and irrigated lands in arid western districts. Gains best growth in rich moist soil; in dry situations should give place to the more hardy green ash.	Transplant seedlings from nursery at end of first year (6–12 in. high). Young seedlings endure dense shade. Till the plantation for three years until the ground shaded. Growth relatively rapid under good conditions; post timber obtained in 10–15 years. Sometimes reaches height at maturity of 100 ft., diameter of 3–4 ft. Renew stand from stump sprouts which give more valuable wood than the original seed forest.	Only moderately shade-enduring. May be planted pure though it thrives when mixed with catalpa, Scotch pine, European larch, black walnut, black cherry or hackberry.	Must be watched for fungous parasites and insect enemies. Autumn foliage purplish brown.

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Basswood (*Tilia americana*) Case A, 5	Wood known as "whitewood," soft, straight-grained, and easily worked; not durable in contact with the soil. Used for general construction lumber, woodenware, paper pulp, trunks, carriage bodies. Desirable for ornament and in shelter belts.	Recommended for moist and well-drained soils in the northeastern States to the Ohio Valley inclusive.	Transplant 1-year-old nursery-grown seedlings. Space 5 ft. each way. Growth rapid during first years, about the same as in Norway maple and red oak. Little cultivation needed. At maturity height 80 ft. Renew plantation by stump sprouts.	Moderately shade-enduring. Pure stand recommended, also mixed stands with white or red oak, white elm, maple, hickories or with white or red pine.	European species less valuable and more liable to insect injury. Flowers valuable to bee-keepers.
Box Elder (*Acer negundo*) Case C, 12	Wood soft and weak, light, close-grained. Used for woodenware, firewood, paper pulp, and an inferior grade of interior finishing and furniture.	Recommended for the treeless West from North Dakota to Texas. Will thrive in many soils but prefers deep, moist loam.	Transplant nursery-grown seedlings to permanent site when they are 1 year old (10–14 in. high). Space 5 ft. by 5 ft. or 4 by 6. Growth moderately rapid. Annual height increase 1–10 ft., diameter increase 1 in. Average height at maturity 40–60 ft., diameter 1–2 ft. Tree short-lived.	Shade-enduring, so may form a lower story combined with white elm, honey locust, black locust, green ash, black walnut or European larch.	Good for windbreaks and as street trees because of hardiness but inferior to many others in every region. Does not grow straight enough for posts and produces less firewood per acre than either cottonwood or willow.

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Hardy Catalpa (*Catalpa speciosa*) Case F, 26	Wood most valuable; light, elastic, very durable in contact with soil. Fence posts may remain sound thirty to forty years. Used in cabinet work. Has high value for fuel, posts, small poles and railway ties.	Recommended for economic planting on fertile lands of the Middle West, south of the 41st parallel. It grows well in the southern parts of Ohio, Illinois and Indiana; in Nebraska south of the Platte River; in eastern Kansas; and on irrigated lands in New Mexico, Colorado and Utah. Will not grow well on poor sandy or stiff clay soils.	1 lb. seed yields 12,000 seedlings. Transplant from nursery when they are 1 yr. old (12–14 in. high). Space 4 ft. each way. Growth most rapid. Annual height increase 2½ ft., diam. increase ½ in. Post size may be reached in 8–10 yrs. Telegraph poles in 20–30 yrs. If entire seed forest cut for posts after 15–20 yrs., it will renew rapidly from stump sprouts.	Not shade-enduring, therefore pure forest recommended, or associates like Russian mulberry or Osage orange which will endure shade and so act as a "filler" to force pruning and straight growth of the catalpa.	In 1888 a ten-acre grove of hardy catalpa was planted at Pioneer, Iowa. In 1908 the grove consisted of trees 25–32 ft. tall, 4–10 in. diameter, worth $2,825.70 in posts. Catalpa plantations should be protected by a windbreak of hardier trees. The common catalpa is much less hardy, and less erect in habit.
Red Cedar (*Juniperus virginiana*) Case N	Wood light, soft, of very fine and even grain, and very durable. Used for posts and poles, sills, railway ties, somewhat in naval construction; but chiefly for lead pencils, cigar boxes and chests. The pencil industry uses 125,000 trees annually.	Thrives as far north as Nova Scotia and Dakota, but reaches best development south of Ohio Valley. Recommended for economic planting especially in Plains States west of Mississippi.	Buy nursery-grown seedlings, or transplant wild seedlings to nursery till 10–12 in. high. Space 4 ft. by 6 ft. Height at maturity 50–80 ft., diam. 2–3 ft. Timber produced in 70–120 yrs.	Plant pure, or with Osage orange or honey locust for windbreaks.	Fragrance of wood utilized as insecticide. The western red cedar (*J. scopulorum*) and the southern red cedar (*J. barbadensis*) give wood of similar grade.

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Black Cherry (*Prunus serotina*) CASE D, 7-8	Wood light, hard and strong. It works easily and takes a beautiful polish. It has high value in cabinetmaking and interior decorating.	Reaches best development on rich, moist, well-drained land. Recommended for the moist slopes of the Appalachians, and west of Indiana through eastern parts of South Dakota, Nebraska and Kansas.	Use nursery stock from seed. Transplant 1 yr. old seedlings, spacing 4 ft. by 6 ft. Relatively rapid-growing and short-lived. Serves well as nurse tree for slower-growing trees. In 10 yrs. attains height of 23 ft., diam. of 6 in. Mature height 40–80 ft., diam. 3 or more ft.	Combine with box elder, green ash, white ash, silver maple or black walnut.	The wood of the cultivated cherry is not used in the United States. Black cherry has various local names, such as rum cherry, whiskey cherry, choke cherry and wild cherry.
Chestnut (*Castanea dentata*) CASE K	Wood light, moderately strong, coarse-grained and elastic; works easily and is very durable. Used in cooperage; for posts, poles, ties and mine timbers; valuable in cabinet work.	Will thrive in dry sandy or gravelly soils. Recommended for planting throughout the East particularly in New England, New York, Pennsylvania, Maryland and the Ohio Valley. Will grow well also in the West on irrigated lands.	Plant 1 yr. old nursery grown seedlings (10–15 in. high), spacing 5 to 6 ft. each way. Grows rapidly; annual height increase 15–20 in. till 30 years old. Renew forest from stump sprouts every 25–35 years. Sprout trees grow more rapidly than seed trees and produce timber in many respects better.	Pure stands recommended renewed by sprout growth. If mixed, plant with white pine, European larch or with maples, ashes or oaks.	Chestnut poles, ties and timber are in great demand. **See note p. 37 on chestnut blight.**

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Coffeetree (*Gymnocladus dioicus*) CASE C, 17	Wood heavy, hard and stiff, coarse in texture, and durable. It works well and takes a good polish. Heartwood reddish. But little known commercially. Valuable for general construction work, for posts, for cabinetwork.	Recommended for commercial planting within its range, New York to west of the Mississippi, south to Tennessee. Also on the semiarid plains of Kansas, Nebraska, Oklahoma, Texas, Colorado and New Mexico. Reaches best growth in deep rich moist soil, but thrives in drier situations, enduring cold winters or hot winds.	Plant nursery seedlings 1–2 yrs. old. Rapid-growing under good conditions: annual height increase 1–2 ft.	Plant in mixture only, with white elm, red elm, hackberry, oaks or ashes. If given a few years start, may be combined with hardy catalpa, Russian mulberry, or black locust.	Valuable for general ornamental planting also.
Cottonwood (*Populus deltoides*) CASE L	Wood light and soft, not durable. Tendency to warp may be overcome by proper methods of piling. Used for fuel, paper pulp, box-boards, unexposed parts of furniture, interior woodwork. Produces a greater amount of fuel for a given period of growth than other trees.	Recommended for economic planting in watered regions of the Middle West. Especially recommended for the Ohio Valley. Is valuable on the northern prairies and the semiarid plains of the Middle West.	Start plantation from nursery-grown seedlings or from cuttings (latter cheaper). Rapid-growing; annual height increase 3–5 ft. for first 10–15 yrs.	Recommended for pure stands, and in mixture with shade-enduring hardwoods, or in moist situations with willow.	Valuable on uplands for windbreaks and along canals and streams to protect the land from overflow.

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Slippery Elm (*Ulmus fulva*) Case G, 3	Wood heavy, elastic, strong, moderately durable, works well. Used for furniture, for ribs of canoes and skiffs, for staves, hoops in slack cooperage, sleigh runners; also for fencing and fuel.	From the St. Lawrence to Florida westward to North Dakota and Kansas. Develops best in rich moist soils of valleys, but hardy in dry sites also.	Transplant 1 yr. old seedlings from nursery, spacing 4 ft. by 6 ft. Rapid-growing; 1 year seedlings 10–18 in. high.	Pure stands recommended. Good mixtures can be made with less shade-enduring hardwoods (white ash, green ash, hardy catalpa, locust or black cherry), or with the slow-growing black walnut, Scotch Pine and red cedar, if the elm is planted after the others have 5–6 yrs. start.	A more valuable tree than white elm. Because of rapid growth serves well as nurse tree for slower-growing species.
White Elm (*Ulmus americana*) Case G, 4	Wood strong, tough and coarse-grained, not durable, difficult to work. Heartwood light brown. Used in slack cooperage, in shipbuilding, for flooring, wheels, agricultural implements.	In deep, fertile, well-drained soil, but thrives also under adverse conditions. Recommended especially for the Ohio Valley, for the semiarid plains of the Middle West and for the northern prairies.	Fairly rapid-growing and long-lived. Reaches height of 5–10 in. first year. Transplant from nursery when seedlings 1–3 yrs. old, spacing 6 ft. or less each way. Size at maturity, height 90–100 ft., diameter 3–7 ft.	Recommended for pure stands also in mixture with the more shade-enduring maples, ashes, and red oak or with black cherry, black walnut, yellow poplar and basswood.	Valuable in shelter belts and for ornamental planting. Known also as American elm and water elm. The cork elm, (*U. racemosa*) of Ontario and Michigan produces wood much stronger and heavier, used in bridge timbers and heavy agricultural implements.
Hackberry (*Celtis occidentalis*) Case G, 2	Wood elastic, of medium weight, hardness, and strength. Used for cheap furniture. May be used as a substitute for elm and white ash; almost equals hickory for fuel.	Recommended for plains and prairies from Canada to Texas. Will thrive in sterile soil where almost any other tree would die. One of the best trees for the semiarid plains next the Rocky Mts.	Seedlings grow 6–12 in. 1st year. Transplant two year old seedlings from nursery, spacing 4 ft. by 6 ft. Mature growth 80 ft. high, 2 ft. thick. Tree lives 150–200 years.	Recommended for pure or mixed stands. Shade-enduring so can be made a lower story with cottonwood, walnut and ash, black locust, honey locust, or Osage orange.	Rivals white elm for shade tree in the Middle West. Good in mixture for windbreaks.

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Shagbark Hickory (*Hicoria ovata*) CASE G, 8	Wood heavy, hard, very strong, tough, flexible, but not durable. Used for vehicles, agricultural implements, axe and tool handles; most valuable fuel; sprouts serve for barrel hoops and in basket making.	Recommended for good soil along the Ohio and tributaries and on fertile hillsides of the Appalachians. Does best in deep, rich, moist soil; will not thrive in hard clay or in sand.	Fairly slow-growing, comparing with white oak. Plant seeds in permanent site because of difficulty of transplanting seedlings (long tap roots). Space 6 ft. by 6 ft. First year's growth 6–9 in. Mature growth, height 120 ft., diameter 4 ft. Renew forest from stump sprouts.	Not shade-enduring. Recommended for pure stands or mixed with hemlock or maple, a lower story planted after the hickory is well started.	Wood in great demand bringing high prices. If trees are grown for nuts, space 20 ft. by 20 ft. Autumn foliage bright lemon yellow.
European Larch (*Larix europæa*) CASE M	Wood heavy, hard, strong, and flexible; very durable in contact with the soil. Largely used in shipbuilding. Very valuable for posts, poles and railway ties.	Recommended for commercial planting in Northeastern, Central and Lake States, to South Dakota. In Iowa, Arkansas and Nebraska it is one of the most promising of trees. Requires deep, well-drained, moderately fertile soil.	Transplant 2 yr. old seedlings from nursery, spacing 4 ft. by 6 ft. Most rapid-growing conifer in Northeastern States. Posts (3–5 in. diam.) grown in 9–16 years. Height at maturity 80–100 ft., diam. 2–3 ft.	Demands more light than other conifers. Do not plant pure. Mix with chestnut, white or green ash, white or slippery elm, Scotch pine, red pine, white pine, Norway spruce or red cedar. A mixture of three or four of these recommended.	Heartwood usually yellowish white, but when tree is grown in cold elevated situation, heartwood becomes reddish brown and harder.

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Black Locust (*Robinia pseudacacia*) Case C	Very tough, elastic and durable. Used for ribs of vessels, tree nails, insular shanks, and in vehicle construction. Equal to bur and white oak for fuel. Locust posts last 15–25 years untreated.	Recommended for any soil, except a wet heavy one, from the Atlantic to the Rocky Mts., south of the 38th parallel. Especially valuable for semi-arid plains of Kansas, Nebraska, Oklahoma, Texas, Colorado and New Mexico, as well as for irrigated lands in Utah, Idaho, Oregon and Washington.	Transplant 1 year old seedlings (1–3 ft. high), spacing 4 ft. by 6 ft. (or 3 ft. by 8 ft. in Middle West). Short-lived but rapid-growing. Annual height growth 2–4 ft., diam. ¼–½ in. for the first 25–30 years. Height at maturity (50 yrs.) 80 ft., diam. 3 ft.	Requires much light. Plant pure, or increase the protective character of the stand by adding Russian mulberry, Osage orange or green ash.	Has been grown with success in California. Autumn foliage pure yellow.
Honey Locust (*Gleditsia triacanthos*) Case C, 18	Wood heavy, hard and strong, coarse-grained; fairly durable. Used for fuel, fence posts, and poles. Most valuable for hedges and windbreaks and for general planting in treeless regions.	Recommended for deep, moderately good soils in Iowa, Nebraska, Missouri, Kansas, Oklahoma, Texas, Colorado and Wyoming. One of the hardiest trees for upland planting in semiarid regions of the Middle West.	Transplant 1–2 yr. old seedlings. Very rapid-growing. Grows 1–2 ft. high first year. Annual height growth. 1–2 ft., diam. ¼–½ in. Posts (3–5 in. diam.) grown in 8–14 years; at maturity height 75–100 ft., diam. 2–3 ft.	Will not endure shade. Give an understory of white elm, or mix with Osage orange, Russian mulberry and black locust.	Recommended as street tree. Equaled in drought resisting power only by Russian mulberry and Osage orange in the Middle West. Late in putting forth leaves. Autumn foliage pure yellow.
Silver Maple (*Acer saccharinum*) Case C, 12	Wood light, not strong or durable. Works easily. Used for flooring, seats and cushion frame in cheap vehicles, flooring, furniture and excelsior. Plantations worth most for fuel.	Will grow anywhere in its natural range through the eastern half of the United States where there are deep soils in moist lowlands and river bottoms.	Short-lived and grows rapidly. Diameter increase ½–1 in. annually. Height at maturity 115 ft., diam. 3–5 ft. Transplant 1 yr. old seedlings which can be procured from nurserymen at very low rate. Renew stand by sprout method.	Somewhat shade-enduring. Plant in pure stand or mix with some ground shading species, such as black walnut, catalpa, white ash, black cherry or black birch.	Good for shelter belts and for park and street trees though there are better trees in every locality. Less hardy than cottonwood or box elder. Autumn foliage yellow.

Names and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Sugar Maple (*Acer saccharum*) Case C, 10	Wood heavy, strong, hard, and dense; not durable; takes a fine polish. Used in cooperage, for implements and vehicles, for interior finish and furniture, for woodenware, spindles and novelties, for musical instruments. Has high value for fuel, charcoal and wood alcohol.	Anywhere within its natural range, the eastern half of the United States. Needs moderately rich well-drained soils. Especially recommended for the Ohio Valley.	Long-lived and relatively slow in growth. Seedlings grow 6–12 in. first year. Transplant 2 yr. old seedlings from nursery. Annual height growth 1 ft. till tree 30–40 years old. At maturity height 120 ft., diam. 3 ft.	Shade-enduring, therefore forms a good understory in plantations of rapid-growing trees. Plant pure or mix with white pine, red pine, white oak, red oak, shagbark hickory, chestnut, basswood or yellow poplar.	Its sugar value in economic planting is greater than its timber value. For sugar production, a pure stand, widely spaced is the rule. Autumn foliage red, yellow and green.
Russian Mulberry (*Morus alba tatarica*) Case F, 20	Wood heavy, elastic coarse-grained, moderately strong, durable. Has high value for posts and fuel.	Recommended for economic planting in rich loam, sandy or clay soils in southern Nebraska, southern Iowa, Kansas, and Oklahoma. Especially good results obtained in the Ohio Valley. Valuable for windbreaks; recommended for silk culture.	Plant nursery-grown seedlings, spacing 4 ft. by 4 ft. Growth fairly rapid, attains height of 20 ft., diameter of 8 in. in 10 yrs. Fence posts produced in 9–15 years. Height at maturity 30–40 ft., diam. 1 ft. Renew stand by sprout method.	Plant pure, close and keep pruned for posts and fuel. Shade-enduring, therefore good for underplanting with black locust, honey locust, black walnut and green ash.	Will endure almost any amount of drought and neglect. Cannot endure cold winters. This tree is a hardy variety of the Asiatic white mulberry introduced into the United States in 1875.
Bur Oak (*Quercus macrocarpa*) Case J	Wood heavy, hard, strong and durable; not distinguished from white oak in the markets. Used for posts, railway ties, and the purposes served by white oak.	On good soils anywhere east of the 98th meridian and in deep rich river bottom soils farther west. Recommended only for rich, moist, well-drained soils.	Slow in growth, like the white oak. Not easy to transplant because of long tap root, therefore, plant acorns in the permanent site; spacing 4 ft. each way. Greatest height at maturity 170 ft., diam. 7 ft. Renew stand by stump sprouts.	Not shade-enduring. Recommended for pure stands or in mixture with still slower-growing species which will force the oaks to taller growth.	One of the most valuable of the hardwoods. Highly desirable for ornamental planting.

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Red Oak (*Quercus rubra*) CASE J	Wood heavy, hard and strong, coarse-grained, moderately durable; not so strong or so durable as white oak, but more easily worked. Used for cabinetwork and interior finish. Not distinguished from white oak in the markets.	Recommended for economic planting on well-drained soils of medium quality or exhausted by cultivation, anywhere in the Northern and Central States.	Grows more rapidly than any other oak. Transplant 1 yr. old seedlings from nursery or plant acorns in permanent site. Height at maturity 150 ft., diam. 5 ft. Renew stand from stump sprouts.	Cannot endure shade. Plant pure or with slower-growing trees such as other oaks, or sugar maple, white elm or white pine. If planted in mixture with chestnut or hickory give it a start of 2–3 years.	By treatment becomes more valuable than white oak for cross ties. Red oak and scarlet oak (*Quercus coccinea* Moench) are highly recommended for use as street trees. Autumn foliage red.
White Oak (*Quercus alba*) CASE J	Wood strong, heavy, hard, tough, close-grained, very durable. Used in ship building, heavy construction work, tight cooperage, vehicles, farm implements, ties, posts and piling, as well as for interior finish and cabinetwork.	Recommended for artificial planting in the eastern half of the United States; especially successful on the lower slopes of the Alleghanies and in the Valley of the Ohio. Can stand drought and cold but thrives best on rich, moist, well-drained loam in protected places.	Slow-growing, diameter increase in ten years in the forest 1 in., in plantations something greater. Height at maturity 60–100 ft., diam. 2–4 ft. (grown under average conditions). Transplant 1 yr. old seedlings from nursery, or plant acorns in shallow furrows or holes in permanent site. Renew by sprout method for ties or posts.	Will not endure shade and does well planted pure. May be mixed with red oak, shagbark hickory, mockernut hickory, chestnut, black walnut, yellow poplar, white elm, white ash or white pine.	Wood of great economic value, and has been so generally used that the supply is nearly exhausted. Valuable street tree. Autumn foliage red and russet brown.

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Osage Orange (*Toxylon pomiferum*) Case F, 20	Wood heavy, tough, hard and strong. Used for railway ties, machinery, wagon felloes, insular pins, tool handles. Most valuable for hedges and windbreaks.	Recommended for economic planting in the middle western states from central Illinois southward and westward to eastern Colorado and New Mexico. Will stand aridity, therefore especially valuable for planting on the semiarid plains east of the Rocky Mts.	Grow seedlings or purchase from nurserymen ($1 to $3 per thousand). Equals Russian mulberry in rate of growth but falls behind black locust. Posts (3–5 in. diam.) produced in 7–11 years. Height at maturity 60–70 ft., diam. 2 ft. Renew by stump sprouts for posts or fuel.	Endures shade, therefore can be made to occupy a lower story in a mixed stand with black walnut, black locust, honey locust or green ash.	Surpassed in hardiness only by red cedar. A 10-acre tract was planted at Farlington, Kansas, in 1878. In 1900 it yielded a total value of $524.04 per acre. The land could scarcely have been used to bring better returns.
Jack Pine (*Pinus divaricata*) Case O	Wood light, soft and coarse-grained, fairly strong and fairly durable. Good for coarse lumber and posts and for ties when treated.	Recommended for north Central States where soil is sterile or sandy but supplied with moisture not far below the surface. Very hardy, growing with success where few other trees will grow.	Short-lived and one of the most rapid-growing of the pines. Transplant seedlings 2–3 yrs. old, spacing 4 ft. by 4 ft. Height at maturity 60–90 ft., diam. 2 ft.	Not shade-enduring. Plant pure or mix with green ash or hackberry which will not overtop it.	Somewhat inferior to red pine and to western yellow pine. Valuable for windbreaks.
Red or Norway Pine (*Pinus resinosa*) Case O	Wood heavier, harder and stronger than white pine, only moderately durable. Used for house lumber and, when treated, for posts, ties and mine props.	Recommended for economic planting in northeastern part of the United States in situations suitable for white pine.	Transplant nursery-grown seedlings when 3 yrs. old, spacing 4 to 6 ft. apart each way. Growth fairly rapid. Attains height of 35 ft., diam. of 6 in. in 30 years. Height at maturity 90 ft., diam. 2–3 ft.	Light-demanding. Plant in pure forest or mixed with trees of slower growth, such as chestnut, red oak, sugar maple or European larch.	If planted close, clears well of lower branches without pruning. Compares with western yellow pine in characteristics of the wood.

Name and Location in Jesup Collection	Economic Value	Where to plant	Growth	Associate Trees	Remarks
Scotch Pine (*Pinus sylvestris*) Case P	Wood strong, elastic, close-grained, works easily; not durable in contact with the soil. Used as fuel, for staves and heading in cooperage, box-boards and general construction work; when treated, suitable for railroad ties and mine timbers.	Scotch pine thrives in a dry atmosphere which fact recommends it for wide planting as a substitute for white pine. Recommended for northeastern United States and especially for the prairie states such as Nebraska, Iowa and Kansas.	Transplant from the nursery when seedlings 3 yrs. old (9–12 in. high), spacing 4 or 5 ft. each way. Growth fairly rapid. In Europe attains at maturity height of 120 ft., diam. of 3–5 ft. Yields mine timbers in 30–40 yrs.	Light-demanding. Plant pure, or mixed with trees that grow more slowly or demand less light. Combinations with European larch, Norway spruce, white pine and red pine are recommended.	More intolerant of shade than any of our native trees except aspen, birch and the larches.
Western Yellow Pine (*Pinus ponderosa*) Case P	Wood light, strong and dense but only moderately durable. Used more extensively than any other wood of the Rocky Mt. region for lumber, railway ties, mine timbers and fuel.	Especially recommended for planting in the sandhill regions of western Nebraska and Kansas, and in the watersheds of the Rocky Mts. and the Pacific Coast below 6000 ft. elevation.	Transplant nursery-grown seedlings. They should be 2–3 yrs. old, having previously had some root pruning and transplanting. Growth fairly rapid. Height at maturity 200 ft., diam. 6 ft.	Recommended for pure stands.	A hardy pine, enduring many kinds of soil and climate. The wood is the most valuable of that produced in the Rocky Mt. region.
White Pine (*Pinus strobus*) Case P	Wood soft, light, straight-grained and easily worked. Used in naval and general construction work but now largely superseded by other woods because of its scarcity. Second growth white pine is used for box-boards, pail staves, matches and woodenware.	Recommended for economic planting on non-agricultural lands of New England, Pennsylvania, New York, the Lake States and the higher slopes of the Appalachians. Will thrive on dry sands or on medium heavy clay and loam soils.	Transplant 3 yr. old seedlings from nursery (6–9 in. high). Annual diam. increase ¼–⅓ in. Height at maturity 150–175 ft., diam. 3–5 ft. Thin stand when 20–30 yrs. old. Box boards produced in 30–40 yrs.; saw timber in 60–70 yrs.	Plant pure or mixed with trees of slower growth, or less light-demanding, such as chestnut, European larch, Norway spruce, red oak and sugar maple.	Especially recommended for reforesting the abandoned farm lands of New England. (See p. 59) White pine trees may live 250 years.

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Yellow Poplar or Tulip-Tree (*Liriodendron tulipifera*) CASE A, 3	Wood light, soft, tough and of fine texture, but not strong; fairly durable. Used for boxes, toys and woodenware, wagon boxes and carriage bodies, slack staves and heading, siding, paneling, interior finish, backing for veneer. Valuable for wood pulp.	Recommended for planting in Tennessee, Kentucky and western Carolinas, also in the Valley of Ohio and its tributaries. Yellow poplar attains its best growth in deep, fertile, well-drained soil having a constant supply of moisture.	Nursery-grown seedlings give best results, transplanted to permanent site when 1 yr. old. Young trees endure shade. Rapid-growing and long-lived (300 yrs). 1–2 ft. is the annual growth for first 40–50 yrs.	Will not endure shade and not strong enough to be planted pure. Combine with slow-growing trees (or give the poplar a few years start), with white pine or Norway Spruce or with a shade-enduring hardwood.	Often used where formerly white pine served. "White" poplar of the lumber market is the wood of trees grown on dry gravelly soil. Highly recommended for shade and ornament. Autumn foliage pure yellow.
Norway Spruce (*Picea excelsa*) CASE N	Wood light, soft and non-resinous; works well and is fairly durable. Used for construction timber, fuel and wood pulp.	Will thrive in a shallow soil and dry climate. Recommended for the Northeastern and Lake States, also for cut over lands of the North and for the northern prairies.	Transplant seedlings 2–3 yrs. old. More rapid-growing than native spruce. Height at maturity 80–100 ft., diameter 2–3 ft.	Pure stands recommended; or mix with white or red pine, with European larch or chestnut.	Serves as a substitute for white pine. Extensively used as an ornamental tree.
Tamarack (*Larix laricina*) CASE N	Wood hard, coarse-grained like red pine but stronger and stiffer; durable. Used for posts, ties, telegraph poles, canoes, spars and masts.	Will endure cold, wet situations. Recommended for planting throughout the northern states from the Atlantic to the Mississippi (up to elevation of 4000 ft.).	Grow seedlings in nursery beds, transplant when they are 2-3 years old. Rapid-growing. 45 feet height growth in 30 years.	Plant pure, or mixed with sugar maple or red oak or with spruce, balsam fir, or white pine.	The red tamarack of the market is the wood of trees grown on cold unfavorable sites.

Name and Location in Jesup Collection	Economic Value	Where to Plant	Growth	Associate Trees	Remarks
Black Walnut *(Juglans nigra)* Case G, 7-8	Wood heavy, hard, strong; works well and takes a good polish; durable. Used for furniture, cabinetwork and interior finish especially in churches; for gunlocks, tool handles, carriage hubs; somewhat in ship building.	One of the most valuable of North American trees for planting in the fertile valleys of the Ohio and Mississippi and in the bottomlands of North and South Carolina, Georgia, Tennessee, Kentucky, Missouri, eastern Nebraska, Kansas and Oklahoma.	Transplant 1 yr. old seedlings from nursery; none but nursery method sure. Growth fairly rapid; 12–14 in. first year; post size in 10–12 yrs. saw timber in 40–60 yrs; May have annual diameter increase of 1 in. Bears fruit in 12–14 yrs.	Not shade-enduring. After the trees have 2–3 yrs. start, underplant with hardy catalpa, hackberry, Osage orange or box elder, shade-enduring trees which can be cut out in 20–25 years leaving the walnut to mature for saw timber.	Black walnut saw logs are exported to Europe, the best bringing very large returns. Autumn foliage bright lemon yellow.
White Willow *(Salix alba)* Case L	Wood soft, light, flexible fairly strong and durable. Used in slack cooperage; for charcoal used in gun powder manufacture; for cricket and baseball bats; for fuel where wood is scarce. Willow posts and poles last only 4–7 years unless treated.	White willow has proved successful for economic planting in rich sandy loam through the northern states south to Virginia and west to Kansas and the Dakotas. Especially recommended for the Ohio Valley and the Northern prairies.	Plant cuttings, spacing 2 or 3 ft. by 8 ft. Rate of growth depends on site, never as great as that of cottonwood. In lowlands, annual height growth 3 ft., diam. 1 in.; on uplands height growth 1½ to 2 ft., diam. ½ to ¾ in. Renew stand from stump sprouts.	Recommended for planting pure or in mixture with cottonwood. Best adapted for holding soil along streams (not along canals or irrigation ditches because the roots grow into the water).	Recommended for windbreaks. Willow produces 2–3 cords of firewood per acre annually on bottomlands. Autumn foliage yellow.

ARRANGEMENT, SELECTION AND CARE OF LAWN AND STREET TREES

WHEN planting trees about the home, arrangement and selection must be considered from other than the economic standpoint. For instance, instead of scattering trees over the lawn and grounds, it is better to mass them on two or three sides of the buildings as a frame for a picture, leaving open space centrally. In this, dense effects may be produced by filling in a lower story with shade-enduring trees or shrubs such as beech, sassafras, dogwood, witchhazel, tupelo, hornbeam and birch. Consider the view and plant no tall trees in position to obscure it. If the grounds are large, little mistake can be made if the picturesque effects of natural forestation are followed; that is, if a brook passes through the lawn droop willows over it, or if there is a small lake fill a point of land with them. If there is a rocky slope make it beautiful with hemlock and beech. Group birches so that they will be set off by a background of dark tree trunks or of evergreens (Fig. 54); plant the low ground-juniper in open stretches. Lombardy poplars add a conventional touch to the scene; locusts distract from the formal. An occasional isolated tree may be effective; oaks, elms, beeches, maples and many others make luxuriant growth when standing alone (Fig. 55). Add some evergreens in all artistic planting if only for the effect in winter. (Frontispiece.)

Plant many trees in cities. They not only give moisture and coolness to the air but also actually make it more fit to breathe by taking out its carbon dioxide and increasing its supply of oxygen (see Fig. 17, p. 20). Trees in congested city neighborhoods tend directly to diminish the summer death rate among children.

In planting along city streets the conventional row must be followed; but on country roads a more natural arrangement should prevail, groups of trees alternating with spaces left open for distant views. Mass tall sun-loving trees with lower shade-enduring trees or with shrubs, and in places allow wild grape and shrubby bittersweet to add their artistic presence. Why conventionalize country roadways? Conformity to the conventional must exist in most that greets our eyes — in city streets, in agricultural fields, in tree plantations. A country roadway may be orderly and yet have a natural arrangement of trees and shrubs, which will have the advantage also of making the place a more attractive rendezvous for our native birds.

FIG. 54. DECORATIVE BIRCHES

On the estate of the late Morris K. Jesup, Lenox, Massachusetts. Plant birches so that they are set off by the dark trunks of other tree or by evergreens

For street planting, deep-rooted trees, like sugar or Norway maple, liquidambar or tupelo are best. They suffer least from having their roots covered by the solid substance of walks and roadbeds. Choice should fall more often on oaks for city streets; they take longer to attain large size, but the result pays for the waiting. Silver maple is often used, but like the box elder is fragile in storms and is short-lived. Some of the best trees for broad thoroughfares in the eastern United States are American elm, tulip-tree, tupelo or pepperidge, honey locust, sycamore, sugar maple and scarlet oak. Tupelo and scarlet oak in autumn are particularly attractive because of their brilliant red foliage. Asiatic trees much used for streets and lawns are ginkgo, horsechestnut, ailanthus and the magnolias. They are worth the attention they receive, except the ailanthus, which, however, has the advantage of growing under extremely adverse conditions.

Very often a sort of care can be given to shade and street trees impossible in the forest and under the conditions of economic forestry. They can be kept in good health, pruned, kept wholly free from insects, supplied with fertilizer and with the proper amount of water, and even artificially strengthened. In pruning, it is best to remove not only dead branches but also living ones to such an extent that there will be left space for the suitable development of those remaining. In removing a branch, cut close to the trunk so that the bark can grow over the wound quickly, preventing the commencement of a cavity through the decay of a stub. Cut through the bark below and at the sides first so that there will be no unnecessary stripping off of bark when the branch falls. If trees are artificially watered, avoid keeping the ground continually wet, but let it dry out between times. When roots are surrounded by water, oxygen cannot reach them, and if this condition continues, the trees die from their inability to breathe. A method has arisen in "tree surgery" by which hollow tree-trunks are filled with cement, all dead wood being first cut out and the cavity coated with antiseptic. There is no doubt that the process may lengthen the life of a tree tens or scores of years. Many great elms, the pride of Concord, Massachusetts, are interesting examples of such treatment.

FIG. 55. TULIP-TREE IN NEW YORK BOTANICAL GARDENS

Many trees make luxuriant growth when standing alone. The largest tulip-trees known have measured 190 ft. in height and 10 ft. in diameter. This species cannot endure shade and in the forest prunes itself of side branches. Forestry Hall, Case A, 3

APPENDIX I.

HOW TO RECOGNIZE A FEW EASTERN BROADLEAF TREES IN WINTER.

Artificial Key to the Twigs.

A. Twigs with alternate buds
  B. Twigs with dark bark.
    C. More or less slender and flexible:.....I pp. 86 to 91.
    CC. More or less stout and stiff:.....II pp. 91 to 93.
  BB. Twigs with light bark.
    C. More or less slender and flexible:.....III pp. 93 to 95.
    CC. More or less stout and stiff:.....IV pp. 95 to 97.
AA. Twigs with opposite buds.
  B. With dark bark:.....V pp. 97 to 98.
  BB. With light bark:.....VI pp. 98 to 99.

I. *Beech, Chestnut, Wild Cherry, Birch, Alder, Elm, Linden and Locust: Trees whose slender and flexible twigs have alternate buds and dark bark.* The twigs of these trees resemble one another closely and are more difficult of recognition than all others.

1. **Beech** (*Fagus americana* Sweet). Beech twigs are known by their unusually long and slender, pointed buds which have many overlapping scales (Fig. 56). The twigs are smooth and reddish brown, and are bent at the points of attachment of the buds. The tree is recognized also by the clean and smooth gray bark of the trunk.

2. **Chestnut** (*Castanea dentata* Borkh.). Chestnut twigs of recent growth have strong ridges extending downward from the leaf scars (Fig. 57). The rounded buds are light brown, have few scales and extend from the twig at an angle of somewhat less than 45°. The bark of the twigs and young shoots is smooth and shining. The bark of the trunk is coarsely ridged lengthwise.

3. **Wild Cherry or Black Cherry** (*Prunus serotina* Ehrh.). The Wild Cherry has rigid-looking stems which are flexible when bent but which break when bent sharply. The small scaly and pointed buds hug the stems closely.

FIG. 56. BEECH TWIG
Known by its slender and pointed brown buds

FIG. 57. CHESTNUT TWIG

Twigs of recent growth have ridges extending downward from the leaf scars

The broken twigs have a peculiarly pungent, bitter flavor and odor. The bark of the trunk is reddish brown and smooth when the tree is young, but scales off in thin fragments as the tree becomes older. The bark resembles that of the black birch but can be distinguished from it by the presence of conspicuous lenticels (breathing structures).

4. **American Gray Birch** (*Betula populifolia* Marsh). The twigs of the gray birch are slender and flexible. They are very tough. The new twigs are rough to the touch. The buds extend at an angle somewhat less than 45° and the twigs are bent where the buds are attached (Fig. 58). The gray birch is characterized by its sprout growth, that is, it seems to have several trunks which start out close together at the ground or near it (Fig. 59). This birch grows in very poor soil, and we associate it with scrub oaks, sumachs, barberries, red cedars and other low trees and shrubs bordering forests and occupying waste land. The white bark of the tree is chalky to the touch; it does not peel from the trunk but remains smooth as the tree grows old. There are conspicuous triangles of dark color on the trunk below the points of insertion of the branches.

Canoe, Paper or White Birch (*Betula papyrifera* Marsh) can be distinguished

FIG. 58. GRAY BIRCH

Gray Birch twigs are rough to the touch and are bent at the points where the buds grow. Rigid, staminate catkins show their winter condition

FIG. 59. GRAY BIRCH IN WINTER

from the gray birch by the fact tha
white shining bark of the trunk contin
splits into thin layers and is frayed i
wind. The white birch grows to grea

Black Birch (*Betula lenta* L.) has
of golden brown color and aromatic f

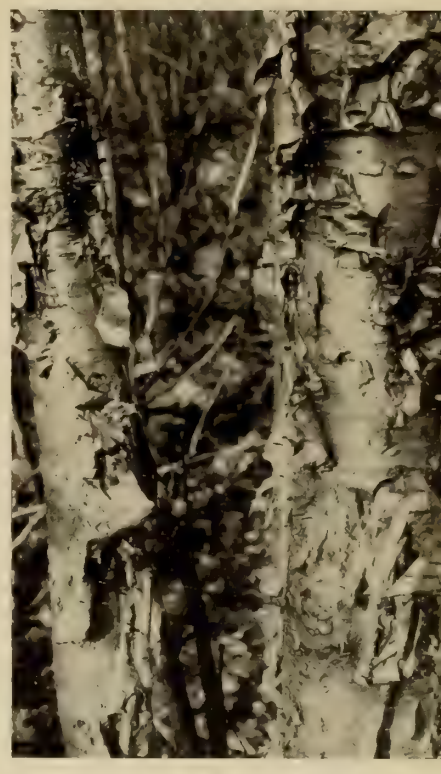

FIG. 60. YELLOW BIRCH
The bark may be frayed into a tangle of ri

differing from those of the gray bir
being brittle instead of tough. The
can be distinguished also by the ba
the trunk, which is likely to be sm
and reddish brown like that of the ch
but lacks the horizontal lenticels of
cherry; it never frays into strips when

FIG. 61. WHITE ELM TWIGS

Some results of a gray squirrel's pruning. He bit off the twigs and ate the flower buds. In the spring the tree seemed in as full leaf as its neighbors

FIG. 62. BASSWOOD

Smooth and brown twigs with fat reddish brown buds

Yellow Birch (*Betula lutea* Michx.). The twigs of yellow birch are less aromatic than those of black birch. The buds are sharp-pointed, light chestnut brown and about one-fourth inch long. The bark is yellow and separates into thin pieces (Fig. 60).

5. **American or White Elm** (*Ulmus americana* L.). The twigs of the white elm (Fig. 61) are difficult of recognition. They are smooth and dark-colored, almost lacking the white spots so conspicuous on many twigs. The small brown buds are scaly and pointed. The alternate branches are given off at right and left in a horizontal plane, are about equal in length, and, although they are not quite at right angles and not opposite like those of red maple, nevertheless at first glance they give the appearance of a miniature telegraph pole with cross-bars; sprays of this character are conspicuous near the top of the tree. The white elm is easily recognized in winter by the vase shape of the tree and the delicacy of the spray.

Slippery Elm (*Ulmus fulva* Michx.) can be distinguished from the white elm by the large size and downy character of its buds and by its mucilaginous inner bark.

6. **Linden or Basswood** (*Tilia americana* L.).

The twigs are smooth and brown, not conspicuously dotted with white. The fat reddish brown buds have few scales and project from the stem at an angle of 45°. The terminal bud is often lacking. The twigs may show the bending at the points of attachment of buds as in the gray birch (Fig. 62). The bark on the trunk is dark and furrowed. The basswood sprouts

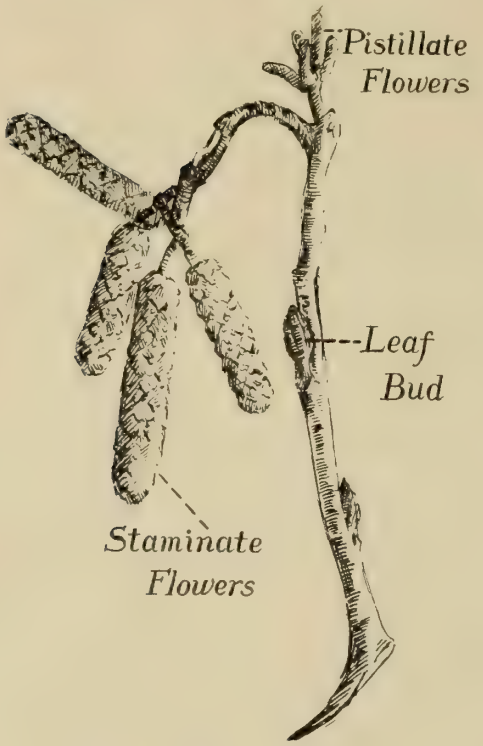

FIG. 63. TWIGS OF SMOOTH ALDER

The buds are stemmed. The drawing shows also the winter condition of staminate and pistillate flowers

out slender branches directly from the trunk.

7. **Common Alder** (*Alnus rugosa* Spreng.). The brittle twigs are grayish brown and smooth, with scattered light spots. Alder can be known by the fact that the smooth oval buds are on short stems of their own. The buds project at an angle of 45° or less (Fig. 63). This alder and the more north-

FIG. 64. WHITE HICKORY TWIG

The terminal bud is always largest. Tough, smooth twigs showing conspicuous lenticels

ern species, Speckled Alder (*Alnus incana* Willd.), grow along brooks and about marshes. The twigs of the latter can be distinguished from those of the former by their downy appearance and by the large number of light-colored lenticels which give the name "Speckled" to the species. These alders seldom reach a height of more than twelve to fourteen feet.

8. **Common Locust** (*Robinia pseudacacia* L.). The recognition of locust twigs presents no difficulty. The twigs are slender, smooth and brown, ridged lengthwise and furnished with pairs of thorns. Between the individual thorns of each pair is a bud almost hidden in the center of a leaf scar: each leaf stem of the locust is hollow at its base and fits over a bud, so that no buds are visible until the leaves have fallen. The bark of the tree is rough and furrowed.

II. *Hickory and Oak: Trees with more or less stout and stiff twigs having alternate buds and dark bark.*

1. **Mockernut or White Hickory** (*Hicoria alba* Britt.). This hickory can be recognized by the large buds which are hard and round with few downy brown scales. The terminal bud is always largest; the lateral buds extend at an angle of 45° or more (Fig. 64). The tough twigs are smooth and reddish brown, and have conspicuous white lenticels. The older twigs are dark gray. The mockernut hickory is a large tree with bark showing wavy furrows.

Shagbark Hickory (*Hicoria ovata* Britt.) has buds with dark scales. The bark on the trunk "shags" off when old.

Pignut Hickory (*Hicoria glabra* Britt.) has twigs that are smooth and greenish brown; they may be somewhat angled.

2. **White Oak** (*Quercus alba* L.) can

FIG. 65. OAK BUDS

Braided in appearance due to the arrangement of the scales. white oak buds are rounded; black oak, pointed.

be distinguished by its rounded buds, which have a braided appearance given by the many closely overlapping scales (Fig. 65, twig at left). Lateral buds are crowded about the terminal bud, producing a cluster. The leaf scars project from the twig. The leaves, which have rounded lobes, are likely to remain on the tree throughout the winter. The "sweet" acorns are in shallow, rough cups. The bark on the trunk of the tree is light-colored and rough.

FIG. 66. BUTTONWOOD TWIG

Conical brown buds are in the centers of the leaf scars

FIG. 67. THE TRUNK OF A YOUNG BUTTONWOOD TREE

Black Oak (*Quercus velutina* Lam.). The large buds (Fig. 65, twig at right) are sharp-pointed and somewhat downy. The twigs are smooth and have a bitter taste. The "bitter" acorns are in deep cups. The bark on the trunk is dark in color. "Oak apples" are found on black oaks.

The white oak, swamp white oak, chestnut oak, post oak and some others, are white oaks, recognized by the light bark of their trunks and the rounded lobes of their leaves. They are difficult of distinction from one another in their winter condition.

The black oak, scarlet oak, red oak, scrub oak and a few others, are black oaks known by the dark bark of their trunks and by the pointed lobes of their leaves. They also are distinguished from one another with difficulty in winter.

III. *Willow, Poplar, Buttonwood: Trees whose light-colored twigs have alternate buds and are more or less slender and flexible.*

FIG. 68. BUTTERNUT TWIG

Shows leaf buds only. The lateral leaf buds are stemmed

1. **White Willow or Golden Osier** (*Salix alba* var. *vitellina*). The twigs of this willow are light yellow in color, smooth, tough, and very flexible. The pointed buds hug the stem; each is covered by a single scale in the form of a peaked cap which may look as though empty at

FIG. 69. BUTTERNUT TWIGS

Showing staminate flower buds

FIG. 70. BLACK WALNUT

Leaf and flower buds. The leaf scars lack the downy ridge conspicuous in butternut

the top. This tree, naturalized from Europe, is very common along streams and marshes. The many native varieties of willow are difficult of recognition even when they have flowers or leaves.

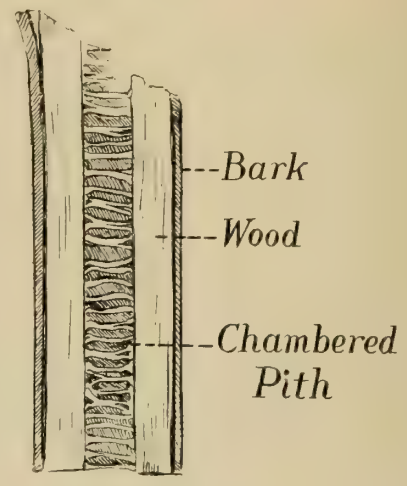

FIG. 71. BUTTERNUT TWIG

Longitudinal section to show the chambered pith

2. **American Aspen** (*Populus tremuloides* Michx.). The twigs of the American aspen are greenish gray and smooth. The pointed buds are long and covered with glossy, gummy scales. The tree is a small one with smooth greenish gray bark.

Large-toothed Aspen (*Populus grandidentata* Michx.) has the same smooth greenish gray bark as has the American aspen, but is a tree of smaller size. Its pointed buds are downy instead of smooth and they extend at right angles from the twig.

Balsam Poplar (*Populus balsamifera* L.) can be recognized by its coarse, ridged twigs and by the large sticky buds which have an unusually sweet odor.

3. **Sycamore, Plane-tree, or Buttonwood** (*Platanus occidentalis* L.). The light-colored smooth twigs are rigid in appearance. The conical brown buds are in the centers of the leaf scars, being formed within the hollow bases of stems and not showing until the leaves fall (Fig. 66). The outer board-like scale covers light-brown silky scales of great beauty. The tree can be known by the bark which comes off in plates, leaving smooth green or white spots (Fig. 67). The balls of fruit hang on the tree all winter.

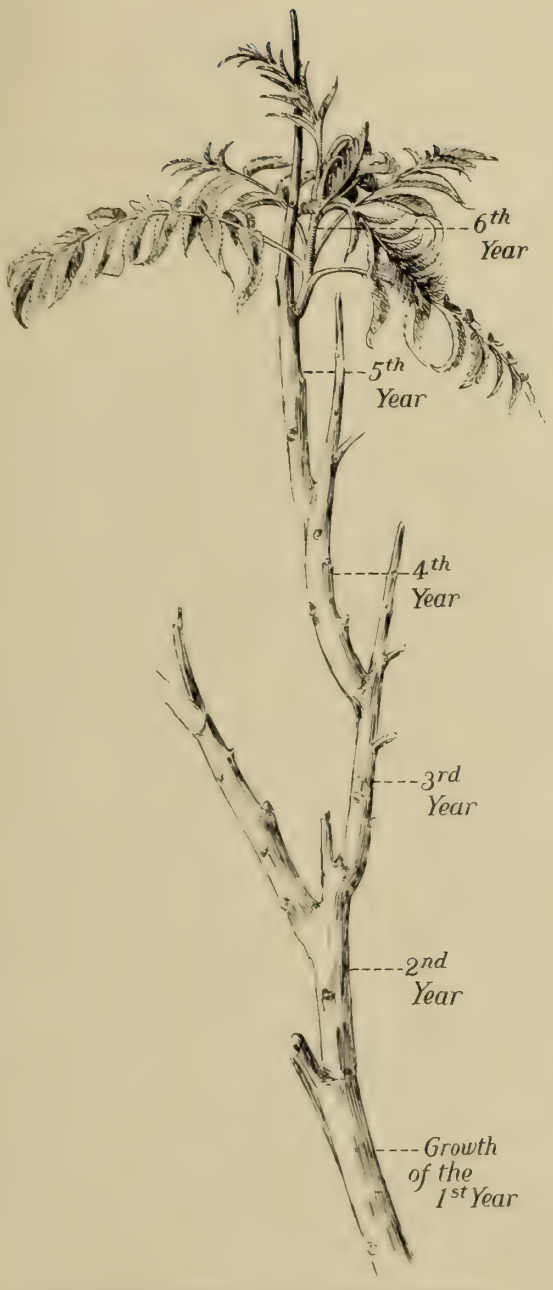

FIG. 72. GROWTH OF THE SMOOTH SUMACH
Recognized in winter by means of its tapering twigs with their dead ends

IV. *Butternut, Sumach, Poison Sumach, Ailanthus, Sassafras, Sweet Gum: Trees or shrubs with light-colored, more or less stout and rigid twigs having alternate buds.*

1. **Butternut** (*Juglans cinerea* L.) can be known in winter by its long, yellowish brown naked buds (Figs. 68 and 69). The terminal bud is much larger than the lateral buds and shows outer reduced leaves which are woolly. The lateral buds are stemmed, and have one or more smaller buds between them and their respective leaf scars. The leaf scars are large and contain three distinct U-shaped scars. Each leaf has a downy ridge above it. The pith consists of transverse chambers, between brown walls, easily seen when the twig is split lengthwise (Fig. 71). The butternut is a large tree with coarse light bark.

Black Walnut (*Juglans nigra* L.) resembles the butternut, but can be distinguished by the gray color

FIG. 73. AILANTHUS, OR TREE OF HEAVEN

Large heart-shaped leaf scars; buds small, two-scaled

of the buds and by the absence of the downy ridge above the leaf scar (Fig. 70).

2. **Scarlet or Smooth Sumach** (*Rhus glabra* L.) has light-colored, smooth stems which are straight and stiff, tapering to a more slender dead end (killed by the frost, or perhaps the remains of the fruit cluster). The buds are small and project from the centers of the leaf scars, being like those of locusts and buttonwoods in this respect.

Sumach of any variety can be recognized in winter by its spreading shape and curious tapering twigs with dead ends. The age of a sumach can be readily told at considerable distance by the curious method of branching from the one to four strongest buds (Fig. 72). The smooth sumach and the staghorn sumach (*Rhus hirta* Sudw.) carry pyramids of scarlet fruit throughout the winter, furnishing food for crows and other birds. The staghorn sumach can be distinguished from the smooth sumach by the dark velvet covering on its stems.

3. **Poison Sumach** (*Rhus vernix* L.). The grayish brown twigs of the poison sumach have extremely small buds above large reddish brown leaf scars that are conspicuously hollowed out. This sumach grows in wet places and has hanging, loose clusters of white berries, which adhere through the winter. This is the most venomous poison among our woody plants.

Poison "Ivy" or Poison "Oak" (*Rhus toxicodendron* L.) is a sumach of vine habit, either climbing fence posts, trees and the like (*Rhus radicans*), or trailing over the ground in a dense carpet (*Rhus microcarpa*).

4. **Ailanthus or Tree of Heaven** (*Ailanthus glandulosa* Desf.). The coarse and sturdy-looking but brittle ailanthus twigs (Fig. 73) have very light bark and conspicuous white

lenticels; the alternate leaf scars are large, more or less heart-shaped, and show many small scars where woody fibres broke away. The buds are small, two-scaled. The pith in the twigs is brown and extensive.

5. **Sassafras** (*Sassafras sassafras* Karst.). The yellowish green, rigid-looking twigs are arranged in bushy sprays. They are brittle and when broken give off an aromatic odor. The terminal buds, which include leaves and flowers, are prominent throughout the winter.

6. **Sweet Gum** (*Liquidambar styraciflua* L.). The young twigs are yellowish in color; the buds are reddish brown and glossy. If the twigs show the blade-like ridges of bark characteristic of sweet gum, the matter of the tree's identity is settled at once.

V. *Horsechestnut and Maples: Trees with dark-colored twigs and opposite buds.*

1. **Horsechestnut** (*Æsculus hippocastanum* L.). The dark twigs are coarse and stout, with prominent opposite leaf scars (Fig. 74). The large brown and scaly terminal buds are covered with a gummy substance. The old bark of the tree breaks away in smooth, square pieces.

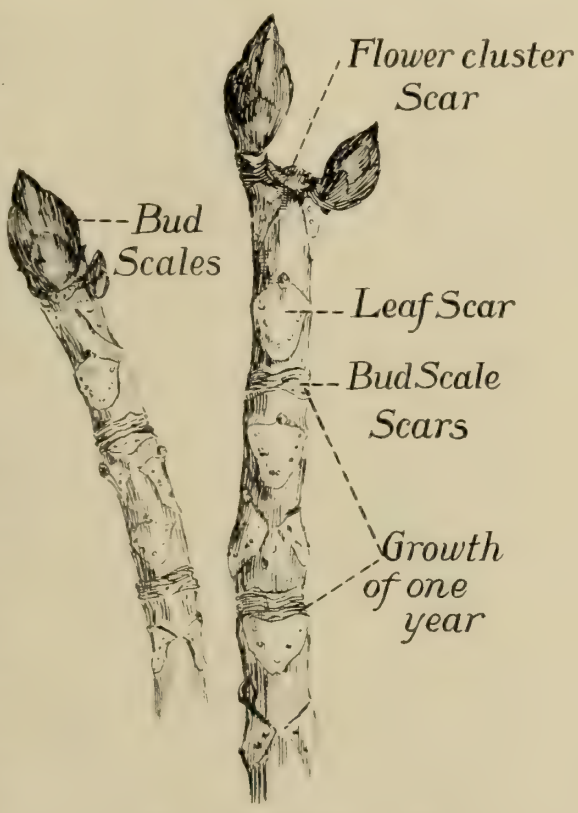

FIG. 74. HORSECHESTNUT TWIG

2. **Red Maple** (*Acer rubrum* L.). Branches, leaf scars, and buds are opposite (Figs. 75 and 76). Spherical flower buds, red in color, may be clustered around the stem adjacent to the leaf buds. Young twigs are red;

FIG. 75. LEAF BUDS OF RED MAPLE

Twigs of latest growth are red; older twigs are brown

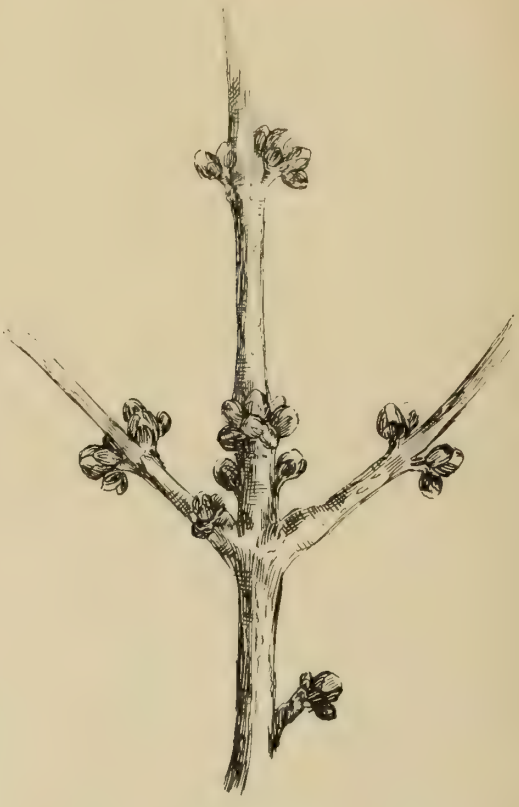

FIG. 76. FLOWER BUDS OF RED MAPLE

Branches, buds, and leaf scars are opposite

older ones, brown. The twigs are often curved like the pendulous twigs of the Silver Maple (*Acer saccharinum* L.). The old bark is smooth and gray, sometimes cracked lengthwise.

3. **Sugar Maple** (*Acer saccharum* Marsh.) has sharp-pointed and scaly brown buds. The old bark is broken into long fissures, having a "ploughed" appearance.

VI. *White Ash, Elderberry, etc.: Trees or shrubs having light-colored twigs and opposite buds.*

1. **White Ash** (*Fraxinus americana* L.). Twigs with light-colored smooth bark; branches, leaf-scars and buds opposite (Fig. 77). The ter-

minal bud (rusty in color) is largest and has but few scales. The stems are flattened at the joints. The old bark is furrowed into diamond-shaped spaces.

Red Ash (*Fraxinus pennsylvanica* Marsh.) can be distinguished by the down on the new shoots. The twigs are relatively slender and are more branched than those of white ash. The buds are dark-colored.

Black Ash (*Fraxinus nigra* Marsh.) twigs are not conspicuously flattened at the joints, they have greenish bark; the buds are black in color. The tree grows in wet places.

2. **American Elder or Elderberry** (*Sambucus canadensis* L.). The opposite buds are small and nearly naked. The twigs are tapering and dead at the tips (compare with sumach, p. 95). The branching is opposite from lateral buds. The American elder seldom reaches a height greater than twelve feet.

FIG. 77. WHITE ASH TWIG

Opposite leaf scars and buds. Twig flattened at the joints

APPENDIX II

KEY TO SOME OF THE CONE-BEARING TREES OF EASTERN FORESTS AND PARKS

A. Leaves not on the tree through the winter.....Larch
(*Larix americana* Michx.)

AA. Leaves on the tree and green through the winter.

B. Leaves in bundles.

C. Leaves five in a bundle.....White Pine

CC. Leaves fewer than five in bundle. (*Pinus strobus* L.)

D. Leaves three in bundle.....Pitch Pine
(*Pinus rigida* Mill.)

DD. Leaves two in bundle.

E. Leaves 4–6 inches long.

F. Leaves flexible from long conspicuous sheathes.
Red Pine (*Pinus resinosa* Ait.)

FF. Leaves very stiff.....Austrian Pine
(*Pinus laricio* var. *austriaca* Endl.)

EE. Leaves less than two inches long.

F. Cones point outward and downward.....Scotch Pine
(*Pinus sylvestris* L.)

FF. Cones point upward.....Scrub Pine
(*Pinus banksiana* Lamb.)

BB. Leaves single in attachment to twig.

C. Leaves attached alternately all around twig.

D. Leaves extending in all directions from twig.

E. Leaves four sided, sharp pointed.

F. Leaves bluish green; cones ½ to 1½ in. long, persistent for many years.....Black Spruce
(*Picea mariana* B. S. & P.)

FF. Leaves yellowish green; cones 1 to 2 in. long, beginning to fall as soon as the scales open.....Red Spruce
(*Picea rubens* Sarg.)

EE. Leaves flat, blunt.....Fir Balsam (young branch)
(*Abies balsamea* Mill.)

DD. Leaves spreading at sides of twig in two ranks.

E. Leaves along top of twig minute.....Hemlock
(*Tsuga canadensis* Carr.)

EE. Leaves along top of twig not reduced in size.
Fir Balsam (old branch) (*Abies balsamea* Mill.)

CC. Leaves attached opposite each other or in whorls closely covering the twig.

D. Spray flat.

E. Cones opening to the base at maturity; scales thin.
Arborvitæ (*Thuya occidentalis* L.)

EE. Cones never opening to the base; scales thick and beaked.
White Cedar (*Chamæcyparis thyoides* Britt.)

DD. Spray 4-angled.....Red Cedar
(*Juniperus virginiana* L.)

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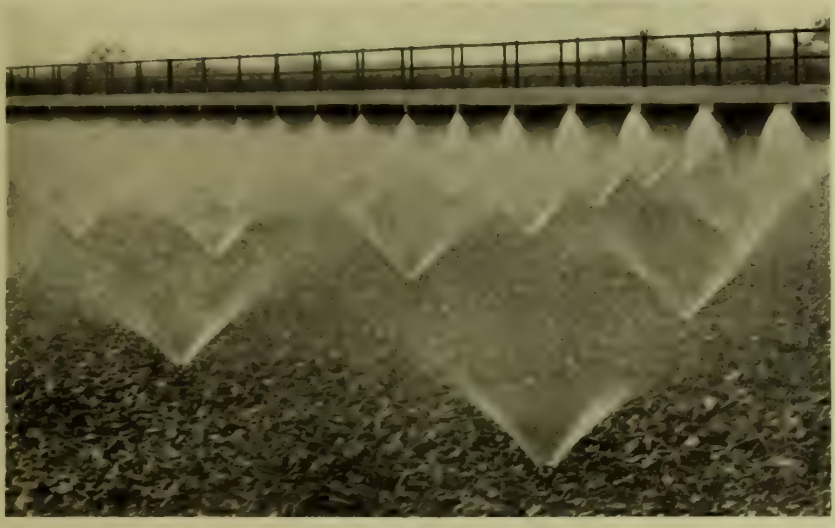
Protection
OF
River and Harbor Waters from Municipal Wastes



TRICKLING FILTERS, COLUMBUS, OHIO

By CHARLES-EDWARD AMORY WINSLOW

Curator of Public Health

GUIDE LEAFLET NO. 33

APRIL, 1911

American Museum of Natural History

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TRICKLING FILTERS, COLUMBUS, OHIO

By means of fixed sprinkler nozzles, sewage is sprayed evenly over the surface of a bed of coarse stone. This method is at present considered one of the most effective of all devices for sewage purification

Protection of River and Harbor Waters from Municipal Wastes

WITH SPECIAL REFERENCE TO THE CONDITIONS IN NEW YORK

BY

CHARLES-EDWARD AMORY WINSLOW, M. S.
Curator of Public Health

NEW YORK
Published by the Museum
April, 1911

NO. 33

OF THE

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OF THE

AMERICAN MUSEUM OF NATURAL HISTORY

MARY CYNTHIA DICKERSON, Editor

PROTECTION OF RIVER AND HARBOR WATERS FROM MUNICIPAL WASTES

WITH SPECIAL REFERENCE TO THE CONDITIONS IN NEW YORK

THE PROBLEM OF SEWAGE DISPOSAL

CITY life presents pressing and peculiar biological problems. When a large number of human beings are concentrated upon a small area the fundamental needs of individual life must be met by new means. Special measures must be adopted for getting food from a wide radius into the center where so much of it is to be consumed. The spread of epidemics which always threaten crowded communities must be guarded against; and the waste products which accompany all living processes must be removed.

This last task, the removal of the city's wastes, is one of the most difficult which confronts a modern municipality. From every large city there pours out a river of waste material which pollutes streams, harbors and foreshores, spoiling what should be the chief pleasure spots of the city and damaging property values, if it does not actually threaten human life and health. By the modern methods of sanitary science these liquid wastes can be purified and rendered harmless and it is with such methods of protecting the purity of inland and seaboard waters that a section of the Public Health Exhibit of the American Museum now deals.

City sewage is a far less offensive substance than might be imagined. To the sight it is simply a grayish liquid with fine flecks of suspended matter in it; to the smell it is inoffensive when fresh, having only a faint musty odor. Analysis shows that the average American sewage contains less than one part in a thousand of solid matter, the rest being water. Of the solid matter half is of mineral nature, so that only a residuum of perhaps four-hundredths of one per cent of organic matter requires especial treatment. It is the vast volume of the sewage stream however, which makes the problem such a serious one. For example, there is now discharged into New York harbor about 500 million gallons of sewage a day. This amount of liquid if concentrated in one place, would fill East River under the Brooklyn Bridge for a distance of one-fifth of a mile. Even four-hundredths of one per cent

of this immense mass of liquid amounts to 800 tons; and this is approximately the amount of organic matter discharged into New York Harbor every day.

The organic matter in sewage, which is the principal source of embarrassment in its disposal, is made up for the most part of imperfectly oxidized unstable molecules which may undergo one or the other of two different series of changes. First, it may decompose or putrefy in the absence of oxygen, with the production of offensive gaseous compounds. Or secondly, under the influence of oxygen it may undergo another process — that of nitrification, a slow burning or combustion which converts the organic matter into nitrates or other mineral substances, without the production of foul odors and in a wholly innocuous way.

Where sewage is discharged without due precautions into the nearest watercourse, the first sort of change is likely to result. If the volume of the sewage in relation to the stream be small, there may be enough oxygen present to care for the organic matter. If, on the other hand, the volume of sewage exceeds the purifying capacity of the stream (which may be taken as about one part of sewage in fifty parts of water) the whole process changes: instead of self-purification, there is putrefaction. Decomposable organic matter accumulates on the bottom and the whole stream or pond is turned into a fermenting pool, the odor from which may produce a serious nuisance for considerable distances from its banks. Conditions like these now exist within the limits of Greater New York in such places as the estuaries of the Gowanus Canal and Newtown Creek.

CONDITIONS IN NEW YORK HARBOR

New York is more fortunate than most cities in its insular position and in the large bodies of water which wash its shores. Even here however, the present methods of disposal by the haphazard discharge of some sewers at the piers or bulkhead lines is manifestly unsatisfactory. So far as the harbor waters as a whole are concerned, it must be noted that the amount of diluting water available is much less than would at first sight appear. The hourly variations are great. Over 3000 million cubic feet of water pass through the Narrows in a single hour at the maximum period of flood.[1] The total ebb at this point is 12,213 million cubic feet; but the

[1] Data in regard to conditions in New York Harbor are quoted from the *Report of the Metropolitan Sewerage Commission*, 1910.

total flood is 11,030, so that the net outflow is proportionately small. In the Hudson River the ebb is 6,910 million cubic feet and the flood 5,740 million. In the East River the figures are respectively 4,068 million and 3,968 million cubic feet and in the Harlem River 176 million and 153 million. The result is that most of the sewage oscillates back and forth instead of passing promptly out to sea.

The general effect of this pollution is manifest in the reduced oxygen content of the harbor. The East River above Hell Gate contains on the

Gathering driftwood from the polluted waters about the steps of the Battery. Photograph from a model in the American Museum

flood tide 92 per cent and on the ebb tide 80 per cent of the oxygen necessary for saturation. Below Hell Gate the values fall to 69 per cent on the flood and 60 per cent on the ebb. In the Hudson River above Spuyten Duyvil there is about 84 per cent of the oxygen necessary for saturation, on both tides; below Spuyten Duyvil the figure falls to 76 per cent on the flood and 66 per cent on the ebb. Samples taken from the eastern end of the Harlem show on the average only 43 per cent of the oxygen necessary for saturation on the flood tide and only 27 per cent on the ebb. The upper East River

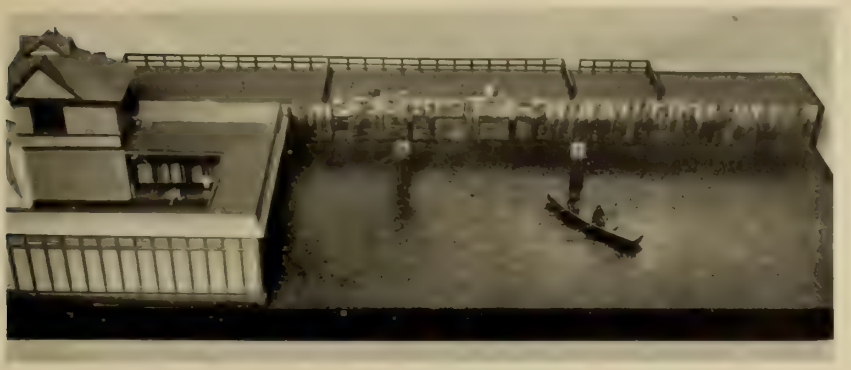
and the upper Hudson are in general in fair condition; the lower sections of these rivers adjoining Manhattan Island are considerably polluted; and the Harlem River is grossly polluted. In the immediate vicinity of sewer outlets the conditions which exist are distinctly offensive to the senses.

Besides these conditions of local nuisance, there are real dangers to health involved in the present method of disposal of New York sewage. The wastes from a city always contain the germs of such infectious diseases as typhoid fever, and those who come in contact with water into which such wastes are discharged are liable to contract the diseases in question. More or less contact is inevitable with the waters immediately surrounding the shores and docks. Thus at the steps in Battery Park and all about the

CLAM DIGGING NEAR SEWER OUTLET, JAMAICA BAY

Shellfish procured from this and similar localities are sold in the city's markets and are occasionally responsible for cases of typhoid fever. Photograph of a model in the American Museum

city, driftwood and other floating objects are picked out and carried by the poor to their homes. All these objects have been exposed to dangerous pollution and may carry the germs of disease. In Jamaica Bay and elsewhere near New York, clams and other shellfish are taken in the near neighborhood of public and private sewers. Some processes of cookery destroy the germs of typhoid but others do not. The amount of disease now caused in this way is probably not large but the danger exists. The most serious of these sanitary problems is that due to bathing in the polluted waters. Free floating bathing establishments are maintained by the City at various points along the water front, often in the near vicinity of

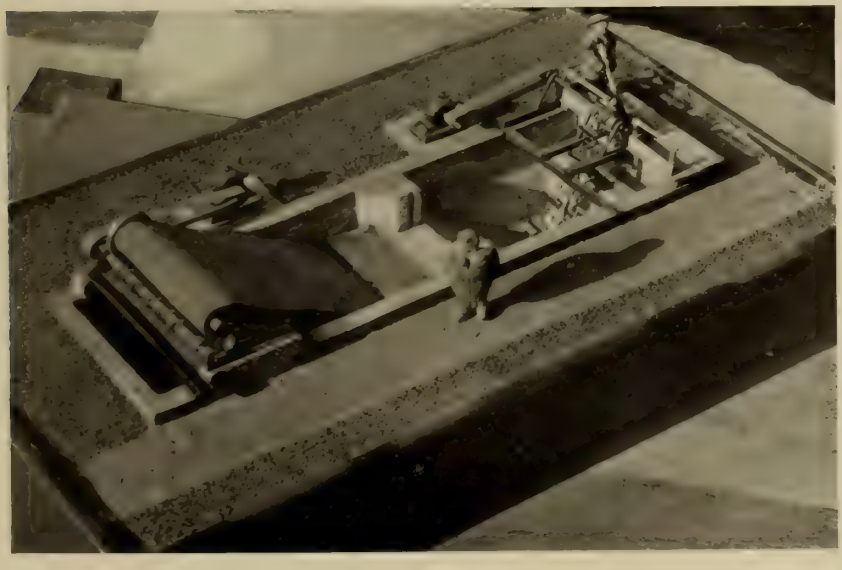


A MUNICIPAL BATHING-PLACE

Free floating baths at various places along the waterfront are placed in close proximity to sewer outlets, thus menacing the lives of many who frequent these baths during the summer months. Photograph of a model in the American Museum

sewer outlets. It cannot be doubted that such conditions furnish excellent opportunities for infection of various sorts.

The safe and inoffensive disposal of the wastes of a large city is a difficult but by no means an insuperable task. It involves one or more of three main processes, according to local conditions — namely, the elimination of



Fine mesh revolving screen and detritus tank for removing suspended solids from sewage. Photograph of a model in the American Museum

Courtesy of J. D. Watson

FINE MESH REVOLVING SCREEN AT BIRMINGHAM, ENGLAND

These screens constantly revolve so that a fresh surface is always ready for use

suspended solids, the oxidation of unstable organic compounds and the destruction of pathogenic bacteria.

SCREENING OF SEWAGE

The first problem in almost every case is the elimination of the coarser floating particles by some form of straining or screening. Sometimes this is accomplished roughly by the use of coarse bar screens with bars half an inch or an inch apart. In England and Germany finer screens of wire cloth with meshes as close as a tenth or even a twenty-fifth of an inch have been used. Such screens are frequently arranged to revolve like an endless belt, so that a fresh area is constantly brought into action and the accumulated screenings are carried upward and automatically brushed off into a trough.

Where it is necessary to remove a larger proportion of suspended solids than can be held back by screening, sedimentation is the next process called into play. Screening alone is sufficient for all practical purposes in some cases, so in others screening and sedimentation will produce an effluent pure enough to be discharged into adjoining waters. As a preliminary to the processes used for final purification, sedimentation almost always plays a part.

SEDIMENTATION

The purifying action of a sedimentation tank depends on the physical factors of velocity and time. If the dimensions of the tank are such that the flow is reduced only to a rate of thirty feet per minute the heavy mineral matter — gravel, sand and the like — will be removed but the finer organic particles will not be affected. Such a small tank as this is known as a detritus tank or grit chamber, and forms a part of practically all sewage works, generally in intimate connection with the screening process.

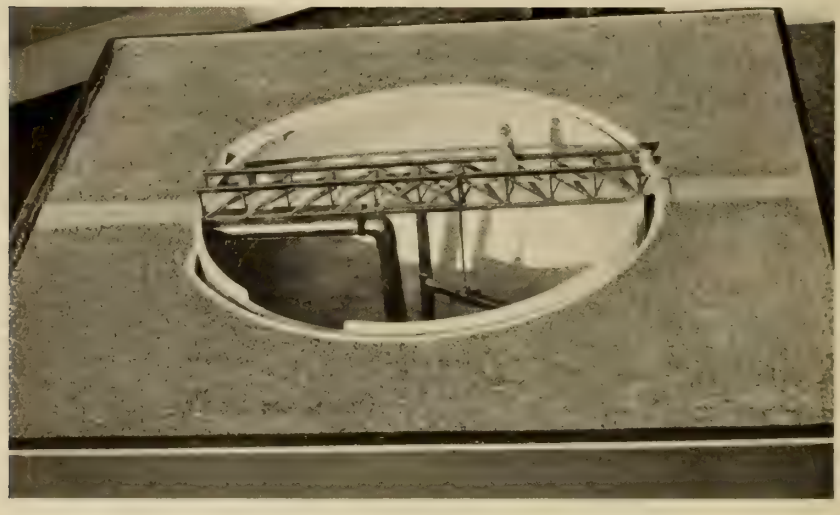
True sedimentation of organic solids requires a velocity as low as six feet per minute, or less maintained for a period of several hours; and the tanks used for such sedimentation are usually rectangular basins of concrete or masonry with a capacity of four to twelve hours flow of sewage. In place of shallow basins of this pattern English engineers, notably at the city of Birmingham, have obtained very satisfactory results by the use of deep tanks with conical or pyramidal bottoms. The sewage enters near the bottom and as it rises and spreads out in the conical section, progressively diminishes in velocity and leaves its suspended solid matter behind, so that the effluent flows off clear at the top. These deep tanks have the added advantage that the heavy sludge can be drawn off by a valve at the bottom

without emptying the liquid above. The ordinary shallow sedimentation basin will not remove more than from 50 to 65 per cent of the suspended solids, while the deep tanks at Birmingham effect a purification of 85 per cent.

Where still more complete removal of suspended solids seems to be called for, the force of gravity may be reënforced by the addition of chemicals which produce a flocculent precipitate, capable of carrying down with it the finer particles, even to some of those which exist in a state of colloidal suspension. This gives better purification but usually at a rather high cost.

THE SLUDGE PROBLEM

In all processes of sedimentation a serious difficulty arises in connection with the disposal of the semi-solid sludge removed from the sewage and accumulated in the bottom of the basins. At the least there is produced some five to ten tons of wet sludge (containing 90 per cent of moisture) for every million gallons of sewage treated. For a community of one hundred persons (assuming 100 gallons of sewage per capita) this would mean one to two hundred pounds of wet sludge a day. With a village of one hundred persons it would be easy to deal with this semi-solid waste by burying it; but with a city of 100,000 inhabitants and 50 to 100 tons a



DEEP SEDIMENTATION TANK

A deep open tank for sedimentation of sewage. Photograph of a model in the American Museum

Septic tank or modified sedimentation basin. Photograph of a model in the American Museum

day to dispose of, the task is far from simple. As a matter of fact this is still a problem which awaits satisfactory solution. Cities on the seacoast can carry their sewage sludge out to sea in tank steamers and dump it in deep water with reasonable success and economy. For inland communities there remain only the alternatives of burying or burning, both of which are costly and unsatisfactory. Utilization seems theoretically promising, but it has not been practically realized except with sewages like that of Bradford, England, which contain an enormous proportion of fats from industrial sources.

THE SEPTIC TANK

There is one form of the process of sedimentation which is specially designed to minimize the sludge problem and which, to a limited extent, does achieve that end. This is the septic tank, associated particularly with the work of Cameron, but in its essential features dating far beyond the year 1895, when he gave it that picturesque name. The septic tank is indeed only a scientifically controlled and regulated cesspool, a sedimentation basin in which the suspended solids are removed by physical processes, but in which they are afterward allowed to remain so that they may be decomposed and reduced to the liquid form by the action of putrefactive bacteria.

The first septic tanks were tightly closed, in the opinion that this was essential to the desired liquefaction. It has since been found, however, that this is unnecessary. All that is essential is that the sewage, or the sludge removed from the sewage, should be retained in a stagnant condition;

the bacteria growing in the liquid consume oxygen much faster than it can be absorbed from the surface, and anaërobic conditions are easily maintained. In such a still pool of sewage sludge, the putrefactive bacteria effect a hydrolytic cleavage of the organic compounds and ultimately split them up into such simple forms as nitrogen, hydrogen, carbon dioxide and marsh gas.

Aside from certain minor details as to size and construction, the Cameron septic tank is simply a brick or masonry basin, covered perhaps with a wooden roof to protect it from the wind, but with no special features to distinguish it from any other tank. If in operation the sludge is removed at frequent intervals, the tank is merely a sedimentation basin. If the sludge is not removed putrefaction sets in, the liquid becomes dark colored, bubbles rise from the bottom and burst at the top and sometimes a thick crust or scum forms over the whole surface. The solids are changed first to liquid and then to gaseous form. The amount of gas evolved is large, four or five gallons from a hundred gallons of sewage, and with closed tanks it is possible to collect this gas and burn it.

The net practical result of the septic process is an appreciable reduction in the amount of stored suspended solids, due in part to the liquefying action of the bacteria and in part to consolidation of the sludge, which makes it more compact and easier to handle. The action of the tank falls far short, however, of the hopes entertained by its original promoters. Half or two-thirds of the sludge still remains to be handled, and the tank itself frequently becomes a nuisance from the evolution of odors of decomposition. Several improved types of liquefying tanks have been suggested during the last few years, of which the one designed by Imhoff for the Emscher Drainage Board of North Germany has in particular attracted wide attention. It is a tank with an upper portion through which the fresh sewage flows and a deep compartment below in which the sludge accumulates and liquefies, and it is said to effect a remarkable destruction of sludge with no obnoxious odors.

DISPOSAL OF SEWAGE BY DILUTION

The processes so far considered are preliminary processes only, which remove from the sewage a larger or smaller proportion of its burden of suspended solids but which do not attempt ultimate purification of the organic constituents, either in solution or suspension. The final aim of sewage purification is to effect a transformation of these organic compounds into innocuous mineral substances by the action of oxygen, and this action is nitrification, practically brought about by the action of certain bacteria.

When sewage is discharged in small volume into a relatively large body of water this process takes place spontaneously. The bacteria normally present in the water attack the organic matter and oxidize it and at the same time the typical sewage bacteria, finding themselves in an unfavorable environment gradually die and disappear. Disposal by dilution, or the discharge of sewage under regulated conditions into adequate bodies of water, is a recognized method of sewage purification, much used in Germany, and often with success. The discharge of too large volumes of sewage into bodies of water which could not successfully digest them has however frequently caused grave nuisances and dangers to health, and the undue concentration of sewage in small bays and in restricted areas near shore may produce local conditions of the same sort. Most inland cities and many seaport cities as well are therefore compelled to seek some special method of sewage treatment before their wastes can be discharged into adjacent water courses.

BROAD IRRIGATION OR SEWAGE FARMING

The most obvious alternative to the disposal of sewage in water is its distribution over the surface of suitable land; and this process of "broad irrigation" is the primitive form from which our modern modes of sewage treatment are derived. Under proper conditions the living earth readily absorbs and digests the foreign materials, by the same processes which lead to the annual disappearance of manure from heavily fertilized land; and the organic matter is not only rendered harmless but is changed into a form in which it serves as food material for the higher plants.

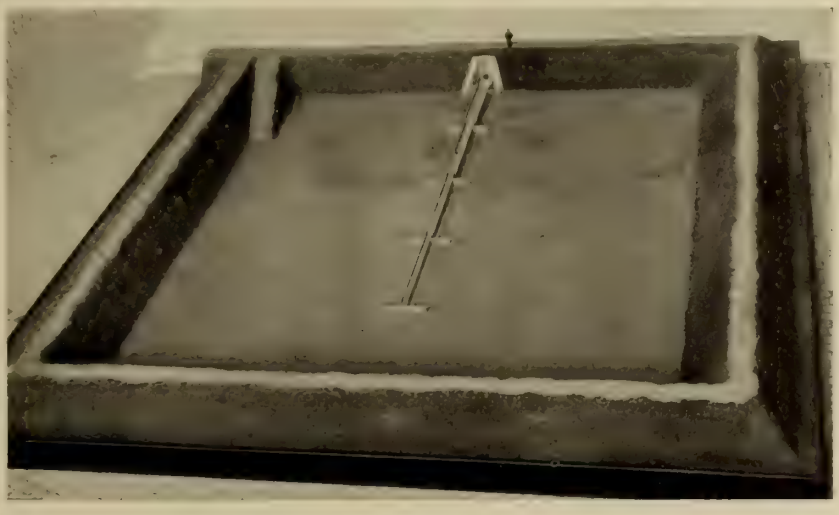
Baldwin Latham, the distinguished English engineer, believed that he had discovered sewers and irrigation areas in the ancient city of Jerusalem; and in China excreta have been utilized for centuries as fertilizer for the fields. At Lausanne in Switzerland, at Milan in Italy, at Bunzlau in Prussia, irrigation was practised in the fifteenth and sixteenth centuries. The extensive development of the art dated, however, from the wave of sanitary reform which swept over England as a result of the *Report of the Health of Towns Commission* in 1844. This report marked the beginning of extensive sewerage construction in the modern sense and with sewerage, sewage disposal was urgently required. With the desire to dispose of polluting material, there grew up in these early days a parallel interest in the possible profit to be derived from crops grown on the irrigated land. The two aims are well balanced in the definition of sewage farming as "the dis-

Courtesy of G. E. Bolling

INTERMITTENT SAND FILTERS, BROCKTON, MASSACHUSETTS

tribution of sewage over a large surface of ordinary agricultural land, having in view a maximum growth of vegetation (consistent with due purification)."

Progress in England along these lines was rapid, so that over two hundred irrigation areas of various sizes were in operation by 1883. Many are still in use to-day and on the continent, Paris and Berlin offer classic examples of this method of disposal. The Paris sewage is distributed on private land and it is not easy to form a sound judgment as to the success of the system. The Berlin farms on the other hand are operated by the city and offer an excellent example of sewage farming at its maximum of efficiency. The farms include 39,000 acres of excellent sandy soil, an area of over sixty square miles. Grass and cereals, potatoes and beets are cultivated and



Intermittent sand filter bed. Photograph of a model in the American Museum

dairies and distilleries are maintained for the utilization of the crops. Even the effluent drains are stocked with fish. The farms are operated by convict labor, and with German intelligence and German military discipline, the enterprise is not only successful as an experiment in sewage disposal but is also economically profitable, for the crops cover all costs of operation and pay for a part of the interest charges on the land.

In general, however, the results of broad irrigation have been by no means so favorable. The process requires large areas of land. The sewage of a community of one hundred persons would need from one to two acres; and the soil must be loose and sandy in character. Where, as in many English towns, the attempt is made to treat sewage on clayey soil, disaster

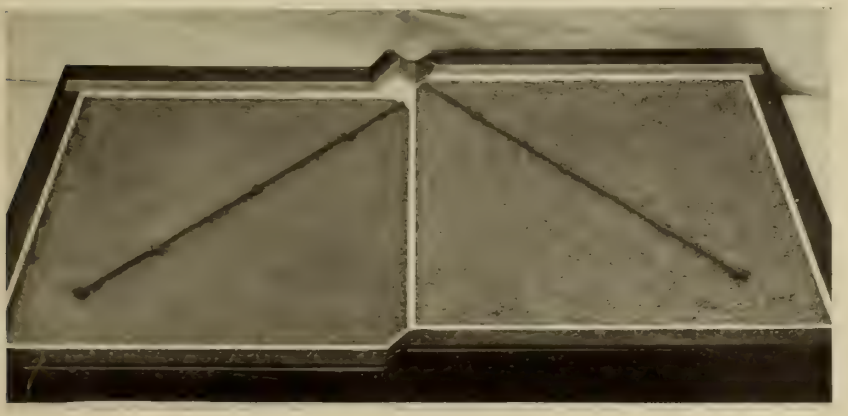
is almost sure to follow. The land clogs and becomes "sewage sick," a local nuisance is created and more or less unpurified sewage must be discharged into the nearest watercourse. Where local conditions and administrative efficiency are less favorable than at Berlin the economic advantage disappears. The most recent studies of the British Royal Commission indicate that cropping of irrigated land scarcely pays for itself — still less contributes toward the cost of sewage treatment. In the arid regions of the western part of the United States where every drop of water, as such, is precious and where the manurial value of sewage is reënforced by its water value, sewage farming becomes really profitable. In many parts of California and Colorado and other western states irrigation is clearly indicated as the best method of sewage treatment. Elsewhere, its application is more than problematical. The idea of converting the wastes of a city into walnut groves and fields of waving corn is an attractive one. The engineer, however, always wants to know the cost; and here, as in other modes of sewage utilization, it is poor policy to recover valuable elements that cost more to recover than their intrinsic value.

INTERMITTENT FILTRATION THROUGH SAND

The real art of sewage disposal began only when the crude process of broad irrigation was freed from the seductive hope of agricultural gain and developed intensively and scientifically as a means for sewage disposal pure and simple. Mainly through the experiments of the Massachusetts State Board of Health at Lawrence, it was shown that the essential process in sewage purification, either by dilution or broad irrigation, was an oxidation of organic compounds by the nitrifying bacteria, and that this process could be carried out much more efficiently by carefully controlling the conditions surrounding it. For a filter bed or substratum for the support of the growth of nitrifying bacteria, a fairly porous sand should be used, and the sewage should be applied in regulated intermittent doses with rests between for the supply of oxygen necessary to the process. By such means the rate of filtration can be raised from 5,000 to 10,000 gallons per acre per day (for broad irrigation) to 50,000 or 100,000 gallons. An intermittent filter of half an acre in area would therefore care for the sewage of five hundred persons while five acres of broad irrigation area would be needed for a similar population.

The construction of intermittent filters in regions like the northeastern part of the United States is extremely simple. This part of the country is

covered with deposits of glacial drift sand, ideal in character for sewage purification. All that is necessary is to expose and level off areas of this sand, to lay lines of underdrains a few feet below the surface to carry off the effluent, and to install devices for discharging the sewage on the surface. A bed may be dosed on one day out of three, or in smaller portions several times a day. In winter the beds are furrowed so that an ice roof forms on the top of the ridges while the sewage finds its way along the furrows between and, although less efficient in winter than in summer, the microbes do their work at all seasons well enough for practical purposes. The effluent from an intermittent filter, properly built and carefully operated, is a clear liquid, colorless or slightly yellowish in color, with no odor or only a slightly



Double contact beds for purification of sewage. Photograph of a model in the American Museum

musty one, practically free from putrescible organic matter and low in bacteria — a liquid that can be discharged with impunity into even the smallest watercourse.

The successful and economical use of the process of intermittent filtration is limited to those regions where ample areas of the right soil are easily available. In clayey or chalky regions, sand beds must be artificially constructed with material brought from a distance, and this would make the cost of the Massachusetts method almost prohibitive. In England where the sewage problem pressed hardest for solution, sand is usually not available and it was almost essential that further improvements should be made.

PANORAMIC VIEW OF TRICKLING FILTERS, COLUMBUS, OHIO

THE CONTACT BED

Mr. W. J. Dibdin, Chemist to the London County Council, was one of the first to attempt to modify the sewage filter so that it would operate at higher rates, and as a first step he naturally sought to build his beds of coarser material. In a notable series of experiments at the Barking outfall on the Thames, he found that the nitrifying bacteria could be grown on fragments of coke or stone as well as on sand and that purification could be effected in such beds if only the sewage were held in contact with the material, instead of being allowed to stream directly through. In sand filters, frictional resistance delays the passage of the sewage, so that time is given for the purifying process. With coarser materials, however, it is necessary to regulate the flow by making the beds water-tight and retaining the sewage in them until purification is completed. This was in outline the genesis of the contact bed.

Beds of this type are simply concrete or masonry basins, filled with crushed stone or coke or slag, in which sewage is allowed to stand for a period of about two hours. After one dose is withdrawn the bed stands empty for aëration for four hours or so and another dose is then introduced, three fillings a day being perhaps an average. A single contact treatment does not commonly yield an effluent sufficiently stable to discharge into a small stream. It is the general practise therefore to use double contact, treating the sewage first in a bed of coarse stone, perhaps one and one-half to two

inches in diameter, and then in a fine bed, of perhaps half-inch material. The rate of treatment, even so however, is much higher than that commonly used with sand beds, 500,000 gallons per acre per day against 100,000. Half an acre of contact beds would treat the sewage from a population of 2,500 against 500 for the intermittent filter. The effluent even from double contact is less highly purified than an intermittent filter effluent. It is dark and somewhat turbid, but it should be free from the tendency to putrefactive decomposition.

THE TRICKLING FILTER

Meanwhile the problem of purifying sewage at high rates was being attacked in another and even more promising manner. The fundamental combination of bacterial films, sewage and air can be effected in various ways. The late Colonel George E. Waring attempted it at Newport in 1894 by blowing air into a bed of coarse stone below, while sewage ran down through it from above. Theoretically this seems a satisfactory process but it has not yet been demonstrated that a sufficient supply of oxygen can be economically provided in this manner. Success was finally reached along another line by resorting to the device of applying sewage, not in bulk, but in a fine spray distributed as evenly as possible over the surface of the bed. By this means the rapid flow of large streams of sewage is prevented and the liquid trickles in thin films over the surfaces of the filling material while the spaces between are continually filled with air, the oxygen content

of which in practise does not become seriously exhausted. The condition is analogous to that which obtains in the process of vinegar manufacture when alcoholic liquor is allowed to run over shavings covered with growths of acetic acid bacteria. Under the name of the trickling bed (called also sprinkling bed or percolating bed) this has come to be considered one of the most promising and effective of all devices for sewage purification.

As in the case of contact beds, almost any hard non-friable material may be used for the construction of trickling filters. In America the size of the filling material is generally between one and four inches and the depth of the beds between five and eight feet. Mr. Rudolph Hering in a very enlightening review of the underlying principles of sewage treatment has recently pointed out that there are three fundamental variables in this process of purification, air supply, total area of bacterial films and time of exposure. The area of bacterial films is conditioned by the size of the filling material and the depth of the bed (the smallest material, of course, giving the greatest surface) and the time of exposure is controlled by the rate at which sewage is applied. Reduced to its lowest terms a trickling filter is simply a heap of stone or other material of such size, depth and texture as to support a bacterial growth sufficient for the work in hand.

The distribution of the sewage over the surface constitutes the most serious difficulty in the construction and operation of the trickling bed. In England, many of the disposal areas are equipped with mechanical distributors of great complexity. Some are designed on the principle of the lawn sprinkler and are revolved by the propulsive force of the sewage as it is discharged. Others are in the form of great movable weirs which pass back and forth on rectangular beds, dripping sewage as they go. At Hanley a mechanical distributor was installed for a quarter acre bed which weighed twelve tons and wore out a forty-five pound bridge rail in two and a half years.

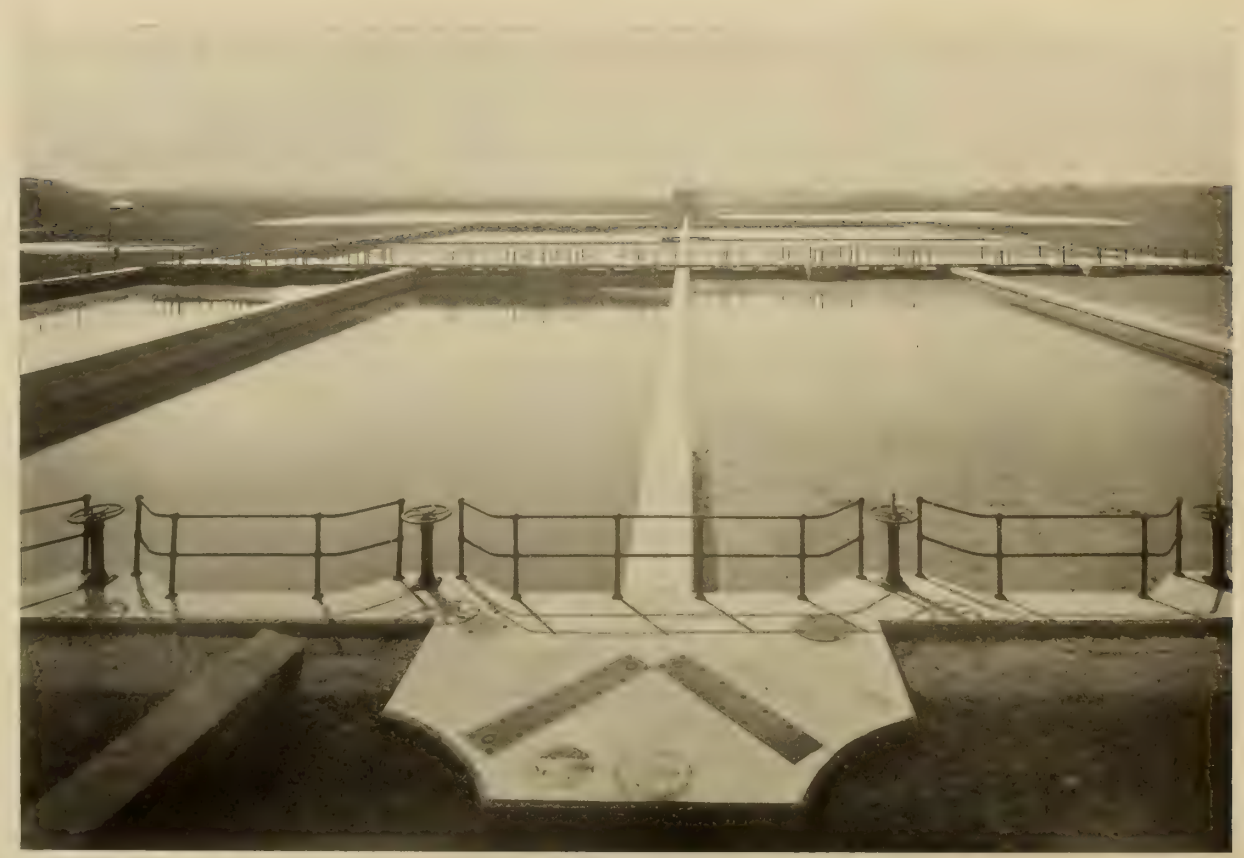
At other English plants, like the most famous of all at Birmingham, and at most American disposal areas, the sewage is distributed by spraying it upward from fixed sprinkler nozzles. This method effects a less perfect distribution than that attained by the English mechanical apparatus but the cost of construction and renewal is much less.

The trickling filter can be operated at a rate of 2,000,000 gallons per acre per day, or four times as fast as the contact bed. Half an acre of trickling beds would care for the sewage from 10,000 persons while a similar area would only do for 2500 persons with the contact bed and for 500 with the intermittent filter. Furthermore trickling beds are practically free from the clogging which menaces the permanency of the contact process.

for the suspended matter comes through trickling beds in the long run in about the same amount in which it goes on at the top, changed only in its chemical nature. The effluent is far less well purified than that of a sand filter. It is more turbid even than contact effluent and in appearance may not even seem very different from untreated sewage; however, the essential changes have been brought about. The more unstable organic bodies have been oxidized and the effluent contains a sufficient excess of oxygen so that succeeding changes will be nitrifications and not putrefactions. At Birmingham, England, where the trickling process has been most ably and exhaustively studied, a sewage flow of 30 million gallons a day is treated first in sedimentation and septic tanks and then on trickling beds, having a total area of about thirty acres; and in dismissing an injunction granted against the city by a lower court the Master of the Rolls has recently decided that the effluent from the Birmingham works actually improves the character of the river into which it is discharged. The large plants recently constructed in the United States at Columbus, Ohio (twenty million gallons), at Washington, Pa. (one million gallons), at Reading, Pa. (two million gallons) and at Mt. Vernon, N. Y. (three million gallons) are all of the trickling type. The trickling filter is indeed an ideal mechanism for solving the essential problem of sewage disposal. It exhibits the simplicity of all scientific applications, which are merely intelligent intensifications of natural processes. A pile of stones on which bacterial growth may gather and a regulated supply of air and sewage are the only desiderata. We meet the conditions resulting from an abnormal aggregation of human life in the city by setting up a second city of microbes. The dangerous organic waste material produced in the city of human habitations is carried out to the city of microbes on their hills of rocks, and we rely on them to turn it over into a harmless mineral form.

SEWAGE DISINFECTION

So far nothing has been said about the problem of bacterial removal. In general this is a subsidiary question in sewage purification. Frequently the elimination of offensive organic decomposition is all that is necessary and bacteria can be allowed to pass with the effluent into the stream, to be removed by the quite distinct processes of water purification from any water taken out for human consumption. Sand filtration effects a very considerable purification in living and lifeless constituents alike; but the



SEPTIC TANKS, COLUMBUS, OHIO

Twenty million gallons of sewage a day can be treated in this recently constructed plant

contact and trickling beds are essentially oxidizing mechanisms without filtering action adequate for the removal of micro-organisms. It is true that in the unfavorable environment of the septic tank and trickling filter, many sewage organisms do die out, but their elimination is incomplete and uncertain. If a nearly germ-free effluent is required some special method must be adopted for bacterial removal. This particular problem has come into great importance of late in connection with the protection of shellfish industries, menaced by the sewage of seaboard cities. Fortunately there has been worked out to meet this need a simple and efficient method, a new chemical treatment, not designed as in the old precipitation processes to remove suspended solids but merely to destroy living germs. The application of ordinary bleaching powder, or chloride of lime, in small amounts of fifteen to thirty parts of bleaching powder to a million parts of sewage will effect a satisfactory reduction of bacteria at a very reasonable cost, as shown first by Mr. S. Rideal in England and by Prof. E. B. Phelps in this country. Baltimore, Maryland, has adopted this procedure as have certain small towns on the New Jersey coast; and it promises to be of use in dealing with certain phases of the New York Harbor problems.

There are many questions still to be solved in the purification of sewage. The removal of suspended matter, for example, urgently demands further careful study; yet the work of the last ten years in England and the United States has blocked out the main outlines of satisfactory sewage disposal practice. The engineer can to-day successfully meet any demand for the purification of domestic sewage; and this purification may be carried to any degree of perfection for which the community in question is prepared to pay. If a clear and sparkling effluent, highly purified bacterially, is desired he can design an intermittent filter for that purpose. If merely a stable effluent which may be discharged into a stream without creating a nuisance is wanted, he can build a trickling filter. If, on the other hand, a disinfected but not organically purified effluent is called for, that end, too, may be attained.

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AMERICAN MUSEUM OF NATURAL HISTORY

Plant Forms in Wax

WAX MODEL OF FLOWERING DOGWOOD, FORESTRY HALL

Department of Preparation and Installation

GUIDE LEAFLET NO. 34

NOVEMBER, 1911

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THE MITLA RESTAURANT in the east basement is reached by the elevator and is open from 12 to 5 on all days except Sundays. Afternoon Tea is served from 2 to 5. The Mitla Room is of unusual interest as an exhibition hall being an exact reproduction of temple ruins at Mitla, Mexico.

Making Wax Leaves

The method of making leaves described in this Leaflet, depending on the use of Mousselaine de Soie, the mysterious "fabric" of the Mogridges, has been largely superseded by the use of cotton batting. The advantages of cotton batting are that the leaf is homogeneous in composition and is less liable to curl or split, and that the stem wire is more securely imbedded in and attached to the substance of the leaf. The material is also more readily obtained, especially in small places. The finer the quality the better, but it is not necessary to use the finest and softest for large leaves.

A thin layer of cotton is spread over the lower half of the mold, the stem laid on this and, if the leaf is thick, a very little cotton laid on the stem; melted wax is then poured over this and the upper part of the mold pressed upon the mass.

The use of molds hardened in paraffin, as noted on page 12, is attended with some difficulty, as wax has a tendency to adhere to them; a simpler method of hardening molds is to boil them for from ten to twenty minutes, according to size, in a strong solution of borax.

If a mold is to be used a great many times a good plan is to place it in hot linseed oil for about 5 minutes and let it dry for a week or ten days before using.

Finally where large numbers of leaves of a kind are to be made, the molds are often made in type metal or bronze and these are fastened to wood or metal frames, hinged together at one end on the principle of an old-fashioned lemon-squeezer. The lower arm may be fastened to a table, and, in the case of large leaves, it frequently happens that two persons may work together to good advantage, one spreading the cotton and pouring the wax, the other doing the squeezing and removing the leaf from the mold. In the case of large parti-colored leaves, for example, green and white or green and red, two colors of wax may sometimes be used to advantage.

In reproducing a cactus the spines must be removed and replaced in their proper position on the wax cast

AT THE EDGE OF THE JUNGLE

Orchid, ferns and vines of India reproduced in wax to show haunt of water monitor and cobra

WAX REPRODUCTION OF CATALPA FLOWERS AND LEAVES

Many of the models in the Forestry Hall are so accurately copied from life that observers, sometimes even botanists, judge them natural instead of artificial and send questions to the Museum concerning methods of preservation

THE BULLFROG GROUP

Birch, alder and willow, pickerel weed, swamp azalea and white water lilies give an unusual effect of realism notwithstanding that all are reproductions in wax

PLANT FORMS IN WAX

SOME METHODS EMPLOYED

IN THE

Department of Preparation and Installation

OF THE

American Museum of Natural History

By E. C. B. FASSETT

NEW YORK
Published by the Museum
November, 1911

NO. 34

OF THE

GUIDE LEAFLET SERIES

OF THE

AMERICAN MUSEUM OF NATURAL HISTORY

MARY CYNTHIA DICKERSON, Editor

A SMALL PORTION OF THE BULLFROG GROUP SHOWING PICKEREL WEED

PLANT FORMS IN WAX

SOME METHODS EMPLOYED IN THE DEPARTMENT OF PREPARATION AND INSTALLATION OF THE AMERICAN MUSEUM OF NATURAL HISTORY

By E. C. B. Fassett

Introduction

THE preparation of exhibits is a primary function of a museum and public appreciation of such an institution is largely dependent upon the excellence attained in this preparation. Moreover, the attractiveness and instructive force of an exhibit often depend almost as much upon the accessories employed in connection with the objects as upon the objects themselves. Thus, a group of birds, of mammals, or of insects must often be arranged to show relation to natural surroundings, therefore requiring foliage which must be reproduced by artificial means since plants in drying do not retain their strength or their lifelike appearance.

The work of the taxidermist in a museum is supplemented nowadays by that of the wax modeler, the glass blower and the plaster worker. Several handicrafts, indeed, contribute to the finished exhibit, including those of the photographer, painter and clay modeler. All these handicrafts have community interests and one is the supplement of the others in the attainment of desired results.

The composition of a group to be assembled must be built on photographic realism in a science museum where accuracy is one of the large

MODEL OF FLOWERING DOGWOOD IN THE FORESTRY HALL

aims. A bird group, for instance, with its painted canvas background and real foreground must be based not only upon actual photographs but on field notes as well, made by an artist colorist. Plants, sections of shrubs, flowers and every significant detail of the immediate habitat, such as sticks, stones, earth, grass and dead leaves, are collected for the realistic foreground. A landscape painter makes the background and the craftsmen strive to blend the foreground with this background and thus bring the entire group into lifelike harmony.

After color notes and photographs have been made of the plants necessary for a certain group, plaster molds are made of the leaves and flowers. These molds are best prepared from fresh specimens, but are obtainable also from specimens preserved in formaldehyde.

The methods which have been worked out in the Department of Preparation of the American Museum all strive for artistic realism of detail, and while the spectator's interest centers in the birds or other natural history specimens for whose proper exhibition the group has been assembled, the accessories also claim appreciative notice. The successful reproduction in wax of the various plant forms is accomplished by persistent experiment, for each new object is in some degree an individual problem. Some of the methods employed, and in many cases evolved by the wax workers in the progress of their work, are explained by the accompanying series of photographs which even without the explanatory notes would give a comprehensive idea of many of the processes.

WHITE AZALEA AND BIRCH OF THE BULLFROG GROUP

LEAF-MAKING

Plaster Molds

An apprentice wax worker is first taught leaf-making, the simplest part of the work. Photographs from the growing plant are made in the field for later guidance. Then in the laboratory of the Museum, after the branches which are to be used

are selected, plaster molds are made of a series of leaves to secure a variety of sizes. The molds, after being thoroughly dried and immersed twenty minutes in hot paraffin, are ready for use.

The simplest mold is the one-piece mold used in the reproduction of many leaves and flower petals. The leaf or petal is laid face upper-

MAKING A MOLD OF A LEAF

A thick heavy leaf (7 in x 8 in.) pressed into a clay bed ready for the pouring of the plaster over it to make the mold

most on a surface of clay, the clay bedded up beneath and around to support the leaf in its natural position and plaster of Paris mixed and poured over it. When the plaster has set, the leaf is removed and the superfluous plaster trimmed away around the impression.

PLASTER MOLD OF A LARGE TROPICAL LEAF

The completed reproduction measuring twenty inches in diameter rests on an ordinary chair

Squeeze molds and piece molds, the former usually of two pieces, the latter of two or more pieces, are made in much the same way although they differ in use. The upper of the two pieces of the squeeze mold

COMPLETED WAX REPRODUCTION OF LEAF

Tropical leaf (13 in. x 18 in.) which has been laid back into the plaster mold to restore modeling of the surface which may have been lost in the trimming process. The supporting wires are very conspicuous on the back but appear only as a part of the venation on the face of the leaf

fits into the lower which is usually concave or cup-shaped. The wax is poured into the lower mold and the upper is forced down into it to squeeze out the excess of wax. The two or more pieces of the piece

mold when held together form a receptacle into which wax is poured through a funnel-like "gate" cut in the plaster.

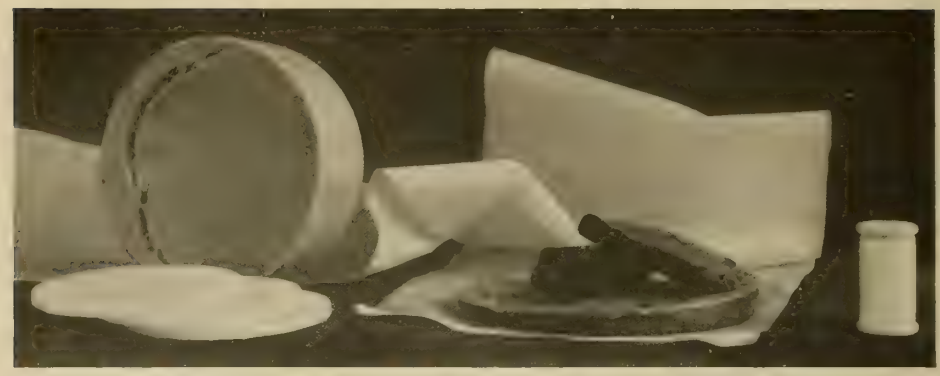
The materials used for the reproduction of the leaf are sheet wax,

A COMPLETED WAX LEAF OF SARRACENIA, OR PITCHER PLANT, AND A PAIR OF THE SQUEEZE MOLDS USED IN MAKING ONE HALF OF IT

There must be a duplicate pair of squeeze molds, minus the keeled part, for the other half of the leaf. The two sections of the wax leaf are welded with a hot tool. Much of the beauty and delicacy of this result depends on the trimming and beveling of the edges of the wax and the artistic feeling displayed by the craftsman

The Materials for the Leaf

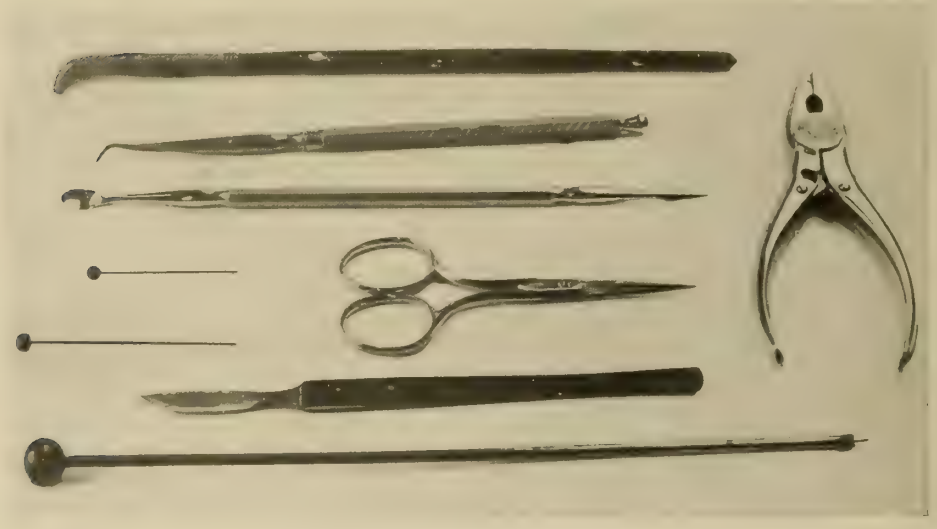
waxed gauze and wire, the sheet wax forming the face of the leaf, the waxed gauze the back and the wire the ribs. The wax should be pure bleached beeswax with a small amount of Canada balsam, that is, about one tablespoonful for each



SOME MATERIALS USED IN MAKING WAX LEAVES AND FLOWERS

Three discs of bleached beeswax; two pieces of wax which have been prepared for use by tinting and by the addition of Canada balsam to give pliability; a piece of waxed gauze and a spool of wire

quart of the melted wax. The wax should be heated in a double boiler. Waxed gauze is prepared by dipping strips of bolting cloth or mousseline de soie into hot wax and withdrawing vertically over a glass rod with



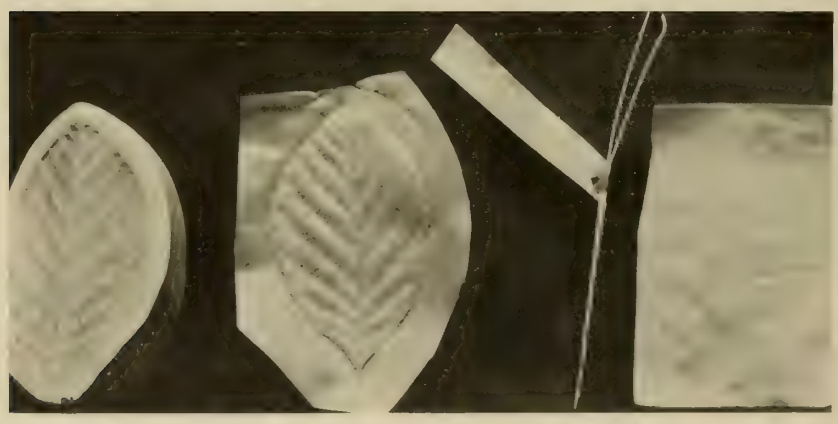
SOME TOOLS USED IN WORK WITH WAX

Hat pins and smaller pins with glass heads used for modeling edges of leaves and petals as well as for many other purposes; a sharp knife for beveling edges of leaves and petals; small scissors for serrating leaf margins; a wire cutter; a spoon-like tool which may be heated to melt and hold a few drops of wax for welding; a general utility tool where heat is needed; a larger agate tool which supplements the fingers in welding the waxed gauze into deep ridges

Many of the wax models in the Forestry Hall reproduce the texture of flowers and fruits in a remarkable way

THE OPERATION OF WAXING THE GAUZE

Wax is brought to a boiling point in a double boiler, tinted the desired shade and a small quantity of Canada balsam added. A strip of gauze (mousseline de soie) is submerged in the boiling wax and then drawn out vertically across a glass rod, with greater or less speed as a thin or thick coating of the wax is desired. A still thicker waxing is obtained by omitting the use of the glass rod and blowing upon the gauze as it is withdrawn



MATERIALS USED IN THE PROCESS OF MAKING SMALL LEAVES

Plaster mold of the original leaf [at the left]; an impression upon a sheet of wax which was laid over the wet plaster mold and worked with the warm fingers into every detail of the mold; the wire midrib partly wrapped with waxed gauze; piece of waxed gauze which must be welded to the wax after the adjustment of the midrib

Two pieces of wire are used for the midrib, one extending a short distance beyond the other for the sake of delicacy. All the work on the leaf until ready for trimming or serrating the edges is done while it lies on the plaster mold

greater or less speed as a thin or thick coating is desired. Still greater thickness of the wax is obtained by omitting the use of this rod, simply dipping the strips of cloth and letting them drip while blowing on the hot wax.

Tinting the Wax

The wax is tinted by mixing small quantities of oil color in a ladle of fluid wax which is afterward gradually added to the heated mass until the desired shade is obtained.

The Wire Foundation

Silk-wound wire, which should vary in thickness according to the size and weight of the leaf, is taken from the spool and stretched until it no longer curls; then it is cut into suitable lengths for the midribs. Heavy wire and additional supporting ribs are used for the largest leaves and are covered with strips of waxed gauze to bring about more complete adhesion with the wax of the leaf. A sufficient quantity of wires, sheet wax and waxed gauze is prepared in advance for the work planned.

The Order of Work

A piece of this sheet wax is warmed over the flame of the spirit lamp or Bunsen burner and applied to the plaster mold, the surface of which has been previously dampened with cold water to prevent adhesion of the wax. The wax is molded with the finger tips until there appears on the wax a good impression of the pattern of the plaster mold underneath. The wire for the midrib is then laid in its proper position upon the wax and covered with a sheet of waxed gauze. The task of welding this gauze to the wax requires care and patience as all air-bubbles must be worked out and the details of venation sharply defined.

PRESSING THE SHEET WAX INTO THE PLASTER MOLD

After placing the wire for the midrib in position, the waxed gauze is welded to the wax. For deeply veined or ridged leaves a rubber tool facilitates the work

THE ADJUSTMENT OF THE WIRE SKELETON TO A WAX LEAF

Before removing the leaf from the mold, the marginal outline is indicated and welded either with the finger nail or some pointed instrument.

The Leaf Margin

The serration of the margins of the leaves calls for deftness and considerable practice. Slightly heat small sharp scissors; then, beginning the cutting at the lower right side of the leaf, let forward, sliding strokes of the scissors alternate

TRIMMING THE MARGIN AFTER THE WAXED GAUZE HAS BEEN FIRMLY WELDED
The position is the same as in the process of serrating the leaf edge

with short horizontal strokes until the tip of the leaf is reached. Then reverse the leaf and cut the left side by a descending process which also reverses the motions used on the opposite edge. After the serration, the leaf is again carefully applied to the mold, the serrated edges are re-welded and the contour of the leaf perfected.

Attachment to the Twig

After the colorist has tinted the leaves either by hand or with the aid of an air-brush, they are ready for attachment to stems. Small stems are made of silk-wound wires wrapped with waxed gauze; they are tinted and then attached to the

THREE PHASES IN THE PROCESS OF CUTTING OUT A LARGE LEAF

In each figure there is presented the back of the wax leaf (6 in. x 3 in.). The leaf was made by the flowing process and has the wire skeleton adjusted and the waxed gauze welded

original wood. In the case of larger stems the original woody branch is used having first been subjected to treatment with glycerine and formaldehyde, which preserves the original bulk of the woody fibre. In attaching each leaf, a hole is drilled at the point of juncture and the wire stem of the leaf passed through and secured. All evidences of the attachment are carefully obliterated by wax and color.

ILLUSTRATING METHOD OF ATTACHING WAX FRUIT AND LEAVES TO THE ORIGINAL BRANCH

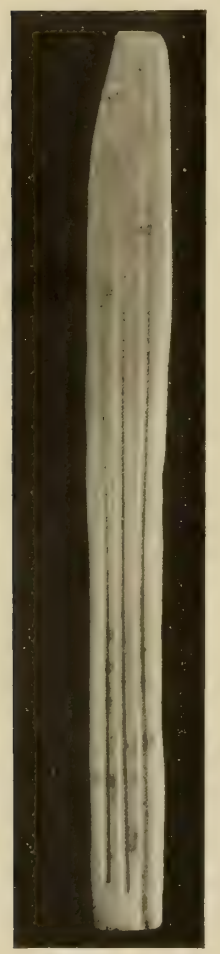
The berries are cast in piece molds, then modeled in more detail by hand. The wire stems are inserted in holes made with a hot tool and the berries are grouped on a wire stem. This stem is wrapped with waxed gauze and covered with a flow of wax. A portion of this heavier wire is left uncovered and inserted into a hole bored in the natural stem or branch. After the wire is secured it is wrapped with waxed gauze, covered with modeled wax and tinted, making a juncture as much like nature as possible

POURING THE HOT WAX OVER A PLASTER MOLD

Flowing Process or Leaf Casting

In making large leaves like hellebore, pickerel weed and many tropical leaves, sheet wax is not used; instead hot wax is poured directly over the mold which has been previously placed in hot water to expel air from the plaster. This flowing process greatly facilitates the work. In the reproduction of a large leaf many wires must be used to serve not only as midribs but as additional supports for the heavy mass of wax. The wire of the

midrib is attached to a heavier wire and wrapped throughout its length with waxed gauze until the proper size is attained. The welding of the waxed gauze must be done with care, the agate tool supplementing the use of the fingers. Finally the leaf is ready for the colorist.



Cactus, Cat-tail, Grass

Cactus may be cast in piece molds and the original spines inserted in the wax. Bladelike leaves of cat-tails may be made from molds. A thin layer of hot wax is flowed into the mold and into this a strip of waxed gauze is pressed. A midrib of fine steel wire wrapped with waxed gauze, is carefully adjusted and over this a second flow of hot wax is poured, and over the wax again a second piece of waxed gauze is welded by passing a hot tool over the surface. Blades of grass are cut from heavily waxed gauze and are modeled by folding them laterally over the edge of a knifelike strip of tin fixed in a wooden base. Very little manipulation is required. No rib is used, but each blade from a short distance above the base is rolled about a wire and several blades are then attached to a heavier wire stem.

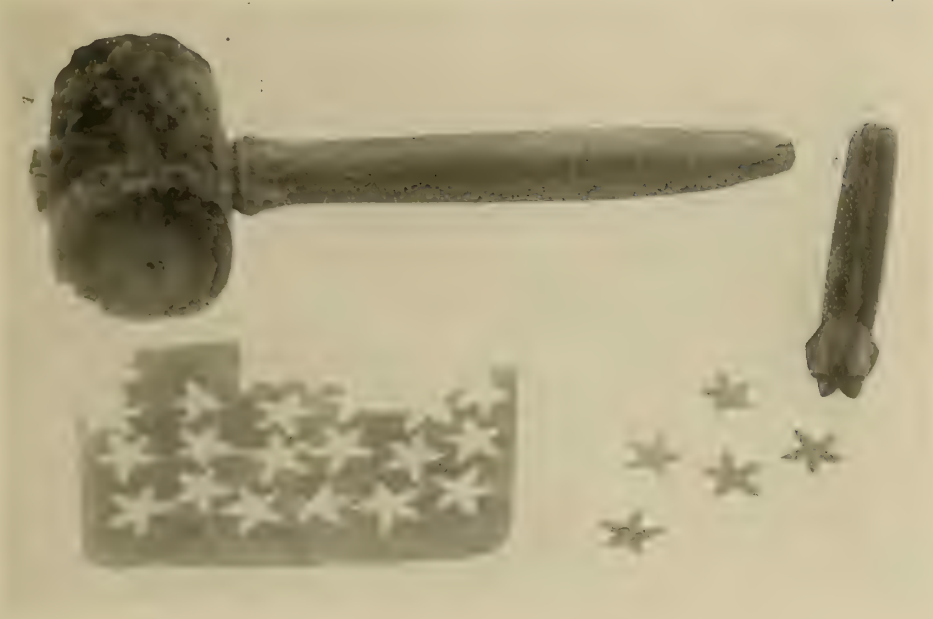
FLOWER-MAKING

Flowers Made with a Die

Flowers are more difficult to reproduce in wax than are leaves because more complex and may be made by various methods. More often they are cut out from waxed gauze with a die, or perhaps with scissors according to a pattern. A die is usually made for simple monopetalous flowers such as pickerel weed, the tube being cut lengthwise and the corolla

PLASTER MOLD FOR MAKING THE BLADES OF THE CAT-TAIL

The three indentations in this mold were made by pouring soft plaster over the fresh green plant. Hot wax is poured into the mold in a thin layer and a sheet of waxed gauze welded into it. Fine steel wires, one extending beyond the other for the tip of the leaf, are wrapped with a strip of waxed gauze and adjusted along the middle line. Over the wire there is a second flow of wax and over the wax a second strip of waxed gauze which again is covered with a flow of wax. A hot tool is then run over the surface and a perfect welding made



DIE, MALLET AND WAXED GAUZE FROM WHICH SEPALS HAVE BEEN CUT

The waxed gauze is laid on a wet block and the die is also dipped into water to prevent adhesion of the wax. A sharp blow from the mallet forces the die through the gauze with a clean-cut edge. A die is used when many small parts like sepals or delicate petals are required

spread out to make the pattern for the die. Such corollas can be cut with one blow of the mallet on the die. Then with a hot tool the tube is welded together, while the petals are curled and adjusted according to life position.

Squeeze Molds for Flowers

For monopetalous corollas of more complex contours such as catalpa, squeeze molds are used, each consisting of two parts the upper fitting into the lower. In this process hot wax is poured over the lower half of the mold and a piece of gauze is pressed into the wax with an agate tool. A second flow of wax is poured over it, and the obverse or upper half of the mold is pressed down squeezing out all superfluous wax. The whole is then thrown into cold water until the wax is hard, when the cast is removed from the mold with the assistance of a glass rod. The impressed wax is trimmed, the rim edges beveled and the edges of the corolla tube welded by means of a hot tool. In still more complex flowers, as some orchids, it is necessary to subdivide and make molds for each half. The welding of the two halves requires skill. The foliage of the pitcher plant also is made in this manner.

Pistils and Stamens

The stemlike parts of pistils and stamens are reproduced from thread which has been drawn through boiling wax under the pressure of a brush. Sometimes fine wires are used in the same way. Stigmas and anthers are made of colored wax applied with a hot tool to the tips of these stemlike parts.

Piece Molds for Thick Buds and for Fruits

Objects of considerable thickness such as buds of water lilies and magnolias, or buds of any large fleshy flower must be cast in piece molds, as also are berries and fruits. There is necessarily some trimming of the tips and stem ends in the making of these forms. A hot wire is thrust into the stem end of the bud or the fruit which is thus fastened to the branch.

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Guide Leaflet Series no.35
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How About the Tent Caterpillar?

An illustration of the Balance of Nature. To what extent is it wise for Man to interfere?

By Frank E. Lutz
Curator, Department of Entomology, American Museum

In the vicinity of New York City the year 1935 was a tent caterpillar year. What that meant for the office force of our department of insect life only those can know who have been at the receiving end of letters, telephone calls, and visits about some insect that has aroused public interest.

It would have been much easier for us if we had been willing to give the simple old advice: burn the caterpillars in their webs and, when winter comes, collect and burn the egg-masses. In fact, not knowing any better, that was the advice we gave, say, fifteen years ago. Since then our doubts about its wisdom have been growing until now we venture to say: "Kill, if you wish, the tent caterpillars on your orchard trees and ornamentals but let Nature take care of the wild trees and *by no means cut down wild cherries*." This called for patient and repeated explaining. Let me try once again, this time in print.

"Balance of Nature"

The tent caterpillar, *Malacosoma americana*, is a native American insect and this fact has an important bearing on the question of what to do about it. If we were considering a foreign insect that, like the Japanese beetle, has been recently introduced without its natural checks, the story would be quite different. But the tent caterpillar has been here for hundreds of thousands—possibly millions—of years; and long before garden clubs and Scouts were organized, or ever man took thought of managing out-of-doors, Nature herself had so arranged things that both the tent caterpillar and natural vegetation, including wild cherries, can live together. The tent caterpillar has been bound by a "Balance of Nature" between it and its environment, including its diseases and insect enemies, in such a way that in any given district the years of caterpillar abundance have been followed by years of scarcity with astounding regularity. If recent organized human interference with natural processes has not thrown the balance out of adjustment, the New York regions that had a peak of abundance of tent caterpillars in 1935 will soon have a scarcity of them for several years. On the other hand, if the balance has been disturbed—well, the result will be interesting scientifically but possibly not pleasing to the wayside committees of garden clubs. When Man interferes with Nature's biological set-up, he is very apt to make a mess of it.

Interference risky

Of course it is true that human civilization necessarily interferes with Nature. The first settlement of white men in America started a whole series of changes in American out-of-doors and the more the country is built up the less "natural" it will be. However, although it seems necessary that we interfere, it is certainly not wise to act blindly or to go too far. The cutting down of wild cherries, the normal food of tent caterpillars, is a case in point.

It has been rather clearly shown by recent work in Europe that when a leaf-feeding species is deprived for several generations of its normal food and is reared on the leaves of some other plant, it will adopt the new food as "normal" and will not go back to the old kind of food

except under compulsion. Adult females of the tent caterpillar now place their eggs almost exclusively on wild cherry, but a small percentage lay on apple and related plants, more rarely on unrelated ones. Now, if the moths find no or few wild cherries, all or most of their eggs will be laid on apple and related plants and many will be laid on other kinds of trees. In some not clearly understood way a preference for the new food-plants would almost certainly be passed on to succeeding generations and the result would be that Man's misguided actions would have changed the tent caterpillar from largely an eater of wild cherry leaves to an eater of other leaves, particularly of apple and related plants.

Wild cherries are safe

Man would have "burned down the barn to get rid of the rats only to find that the rats had moved into the house." Not only is this true of the tent caterpillar, but it is true also of scores of other species of wild cherry insects that, if it were not for the wild cherry, might conceivably become feeders on other trees.

Furthermore, many people want the "barn." Therefore, when I have told these people that the tent caterpillar is not as yet a really injurious species, partly because it so largely confines its attention to wild cherry, I have been asked why I place no value on wild cherry. I do. I regret that my own yard is too small to accommodate a patch of them and, were it only for the charm they add to the wayside, I would encourage their preservation along the borders of fields. However, the tent caterpillars, even at their peaks of abundance, do not seriously injure the wild cherries. Three weeks after complete defoliation these trees or bushes are in full leaf again and complete defoliation occurs only in years of caterpillar abundance.

But, should we not do something to prevent even this temporary defoliation? Perhaps we might if we knew more about it and thought that the gain justified the cost. However, we do not yet know enough to be prepared to take over Nature's care of out-of-doors; and some of the things that we have done in the case of the tent caterpillar do not now seem to be wise. This brief article can do no more than hint at the complexity of the situation and the meagerness of our knowledge concerning even this common insect.

Probably most of you have seen the rather motherly-looking brown adults of *Malacosoma americana* but possibly many of you have not recognized them as grown-up tent caterpillars. They appear in early summer, and each female, if in good health, places a band of eggs, laid one against another, around a twig. These eggs are smeared with a frothy material that dries into a shiny, dark brown protective cover, as is shown by the accompanying photographs.

Development of caterpillars starts at once and, if no disease or insect parasite is present, each egg will within a few weeks contain a perfectly formed caterpillar doubled up so that its head and tail are together at the outer end of the egg. Here progress usually stops until the following spring. Occasionally a few of the young caterpillars break through the eggshell and protective covering in August, and more rarely still, whole families hatch; but this precociousness does not seem to be an advantage to them.

Birth to death

When wild cherries begin to break into leaf in early spring, the tent caterpillars that have spent the winter, each in the cramped confines of its own eggshell, come out as though at a signal. Brothers and sisters huddle together on the deserted egg-mass for a while, straightening out their bent bodies, and then they move to their first meal of tender, new leaves. As they go they spin a thread of silk. In fact, a large part of the lives of these caterpillars consists of eating leaves and spinning silk. When clustered together after eating, they move from side to side, spinning the silk that forms the "nest"; when going from nest to food and back again, they spin threads of silk on the bark until the family has delicate carpets on which to walk.

Family life is abandoned when the caterpillars have become fully grown and each strikes out for itself to find some sheltered place in which to spin its cocoon. In the privacy of this cocoon it changes to its pupal form, looking somewhat like a small, fat, brown torpedo. Then quickly follows the marvelous transformation that results in the winged adult.

That, briefly, is the story of a lucky tent caterpillar's life, but by no means all tent caterpillars are lucky. In all of their stages they are in danger of attack by the natural agents that control their abundance. It would be well for Man to learn more about these natural controls and to avoid interfering with them.

There are thousands of kinds of insects that live by eating other kinds of insects. Some catch their prey, kill, and devour it at once. Good examples of these "predacious insects" are the caterpillar hunters, moderately large beetles of the genus *Calosoma*. Others, not very aptly called "parasitic insects," go about their predatory missions in a more leisurely and often complicated manner. Typically, the mother of a "parasitic insect" lays her eggs in her victims. The larvæ that hatch from these eggs live in the victims until they, the parasitic larvæ, are fully grown. Then they may pupate there or they may crawl out to pupate. In either case the victim, rather ironically called the "host," dies.

Helpful parasites

Many of these parasitic insects are wasplike creatures and some are so small that their entire larval and pupal life is passed within a single egg of their host. For example, in the latter part of July Mrs. T. S. Homans kindly sent us tent caterpillar egg-masses from Long Island. Although these eggs had been laid only about a month before they were received, and the caterpillars would, for the most part, not hatch until the following spring, tiny adult wasps were already emerging from them. Twenty-five or 50 were crawling about in the packing box when it was received, and 183 more emerged from 100 of the caterpillar egg-masses during the next month. In nature these wasps would probably have laid their eggs in the eggs of some other moth, the resulting young wasps would have passed the winter in the despoiled eggs of that moth, and adults would have been ready next summer to attack the eggs of a new brood of tent caterpillars. Suppose there had been an organized campaign last summer to collect and burn tent caterpillar egg-masses. The burning would have destroyed thousands of these wasps that Nature uses in her control of not only the tent caterpillar but also of the other caterpillars. We do not, as yet, know what those other caterpillars are, but we may be reasonably certain that, from the human viewpoint, they are undesirable. One of the troubles with Man's interference with natural processes is that its bad effects do not stop with the matter immediately in hand but involve a whole complex of delicate balances.

To be sure, most of the organized campaigns for collecting egg-masses wait until winter, when the egg-masses can be more readily seen. By that time the wasps just mentioned would be out of the egg-masses and escape burning. But that is not the whole story. There are other kinds of parasitic wasps that pass the winter in the egg-masses and emerge very early the next spring along with the tent caterpillars that have not been eaten.

Nature's forces rally

For example, Miss Olsen, secretary of our department, kept a careful record of 100 egg-masses from each of four localities near New York City. About 62,000 tent caterpillars and about 2000 tiny wasps came from these 400 egg-masses in the spring. It is true that destroying egg-masses in those localities the preceding winter would have killed about thirty caterpillars for each destroyed wasp, but we must remember that this was near the peak of caterpillar abundance and that Nature was just building up her forces to control the species. Furthermore, we do not know what good work these tiny wasps do between the time that they emerge from tent caterpillar eggs in early spring and the time that their children parasitize the next laying of tent caterpillars in midsummer. On the other hand, it is also true that a careful study has not yet been made of these parasitic wasps that spend the winter in the tent caterpillar egg-masses. There is a possibility that at least some of them were "secondary parasites" living at the expense of the wasp larvæ that had earlier eaten eggs of tent caterpillars. Clearly, "secondary parasites" that kill the "primary parasites" that kill the tent caterpillar are friends of the caterpillar and it might be to Man's advantage to get rid of them. Quite as clearly, however, the situation is so complex that, without more knowledge of the facts about insect life in general and about the natural history of the tent caterpillar in particular, we are not ready for drastic interference with Nature's balance.

But what about the tent caterpillars that do succeed in hatching? In years of caterpillar abundance caterpillars are certainly abundant. Miss Olsen's figures showed an average of 155 caterpillars per egg-mass last year, even including the parasitized masses. As an example of occasional abundance, Mr. A. Klein brought me a prize twig having eight such egg-masses on less than a foot of twig. Before considering

Nature's further checks, let us look at the simple matter of starvation.

Natural control

Suppose the wild cherry bushes or trees in a given area could support an average of 500 tent caterpillars each. In a peak year there might be an average of ten or more egg-masses to each wild cherry. Taking 150 as a rough average of the number of tent caterpillars hatching from each egg-mass, there would be 1500 or more caterpillars to be fed by trees that could feed only 500. In such a case the only caterpillars that would not starve before they were able to mature and leave progeny for the next year would be the few that were lucky enough to be on isolated bushes upon which only two or three egg-masses had been placed by the previous year's moths.

Now suppose that well-meaning people had encouraged children to gather egg-masses in the previous winter and that the children had been so thorough that they got eight or nine out of every ten egg-masses. That would leave an average of one or two egg-masses or about 200 caterpillars on each 500-caterpillar wild cherry and, so far as food supply is concerned, all could come to full-fed maturity in an area where few would have done so if the well-meaning people had let Nature alone. Furthermore, those 200 caterpillars per average bush would not suffer from other effects of overcrowding such as contagious diseases.

The working of disease when the caterpillar population is dense was very vividly illustrated in a waste field near my home last summer. Before the caterpillars were half-grown, dead individuals were seen here and there, and a week later there was scarcely a nest in the whole field that was not festooned with the limp skins of dead and dying. There will be very few tent caterpillars in that field next spring.

This epidemic of caterpillar diseases was not so striking in my own yard but it was there. I had purposely allowed several families of tent caterpillars to remain on each of my two apple trees and did not spray the trees. (If the owner of apple trees wishes a crop of good apples he should spray to kill the larvæ of the codling moth—a foreign insect—plum curculio, and other pests. These sprays also kill tent caterpillars. Therefore, when a tree-owner complains that tent caterpillars are eating his apple leaves, we need not feel very sorry for him, because it is evident that he was not taking good care of his trees at any rate.) Long before the usual time for the tent caterpillars to leave the trees in their search for a protected place in which to spin cocoons and pupate, many of the caterpillars became restless and crawled to or near to the ground. Most of these were sick, some of them apparently having the same disease that caused the wholesale deaths in the waste field, others apparently having something else wrong with them. From time to time I caged samples of tent caterpillars that were leaving my trees. Of 880 such caterpillars only 117 lived to spin cocoons; and of these only about 50 emerged as moths; and most of these adults were so deformed and sick when they emerged that they were in no condition to perpetuate the species. Natural control was certainly acting in my yard.

Nature's time-tested technique

As was discovered some years ago by Mr. Brown at our field station for the study of insects, another important disease affects the ovaries of the adult moth, preventing her from laying eggs. The importance of parasitic insects in controlling the abundance of plant-feeding ones can scarcely be overestimated. How important in comparison with diseases they may be in controlling the tent caterpillar we do not know. It is quite possible—indeed, it seems almost probable—that, in the case of a gregarious species such as the tent caterpillar, diseases may be the more important. Possibly if we knew more about these and other diseases affecting insects, we could keep cultures of the various diseases on hand and spread them in places and at times that would be to our advantage; but at present, not having the knowledge, it would seem wise to avoid doing anything that might interfere with Nature's time-tested technique.

I have already referred to the insects that parasitize the eggs; but caterpillars that succeed in hatching are by no means free from their insect enemies. The majority of parasitic "wasps" and flies wait until their "hosts" have hatched. The list which the U. S. Bureau of Entomology and Plant Quarantine kindly sent me records 6 kinds of wasps reared from the eggs and 37 kinds of wasps and flies reared from the larva and pupæ of the tent caterpillar. From the relatively few cocoons of the tent caterpillar that we collected last summer we reared scores of these parasites. They emerged in mid-summer and, since the next chance they

could have at tent caterpillars would be about ten months later, they undoubtedly attack some other kind of caterpillar in the meantime.

Nature's cycle

Well, I have given you a very sketchy account of some of the troubles that beset tent caterpillars. In my own neighborhood they were so abundant last year that the death rate from starvation, disease, and insect enemies was extremely high. As a result, I expect far fewer tent caterpillars there next season. And, since both diseases and insect enemies increased last year and will probably be carried over the winter, I expect that such tent caterpillars as there are next season will have a very hard time. Consequently, there probably will be still fewer two years from now. Eventually the diseases and insect enemies will largely die out, because families of tent caterpillars will be relatively few and far between. Then the number of tent caterpillars will increase again to a peak, completing the cycle. Meanwhile, the wild cherries will not have suffered serious injury and, with a little care on our part, neither will our orchard trees and ornamentals.

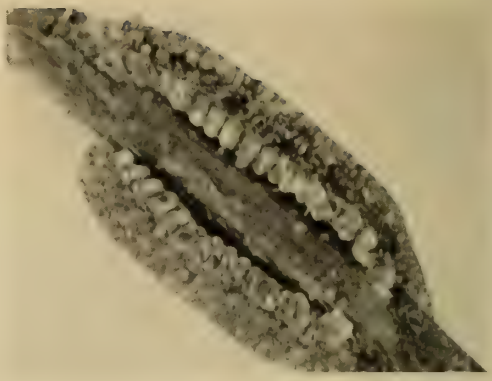
Unknown factors

It is for such reasons as these that we now discourage so far as we can Man's wholesale interference with Nature's control of the tent caterpillar. Let Man take care of his cultivated trees but let Nature take care of the wild cherries.

If I have given you the impression that we know very little about the life of this common insect and its complex relations with other living things, I shall not be disappointed. A realization of ignorance is the beginning of wisdom! As a matter of fact, we know even less about the lives of thousands of other kinds of insects in our neighborhood than we do about the tent caterpillar. The study of insects is still in its infancy. We are still largely in the preliminary but fundamentally important stage of describing and naming the species. One of the greatest needs in biology today is intensive work on the biology of insects. For this work we need field laboratories equipped with capable research men. The search for the "unknown factors" in the biological equations involving human affairs is a matter for pure science, but it is extremely practical as a necessary foundation for applied science—in this case for finding solutions to the problems involving our relations with insects. Until these factors are known, we can have no satisfactory solutions of the problems, and, unless they are found, it may well be that the "insect menace" will become a real one.

A parasitic wasp—an enemy of caterpillars, a friend of Man

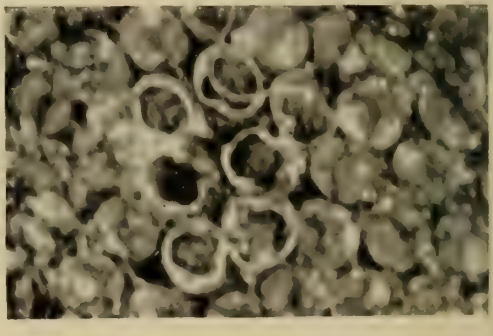
In a peak year. On less than a foot of twig shown above there are eight egg-masses. Under such crowding none of the caterpillars will mature



(*Above*) *Each egg-mass is laid in a band around the twig and smeared with a protective sheath* (*Half of band removed*)

(*Below*) *Here the twig has been removed.* (*About four times actual size*)

(*Below*) *Eggs enlarged about fifteen times. Tops of seven are removed, showing caterpillars in six*



Tent Caterpillar?

(Above) A group of newly hatched caterpillars on egg-mass

(Below) A fully grown caterpillar

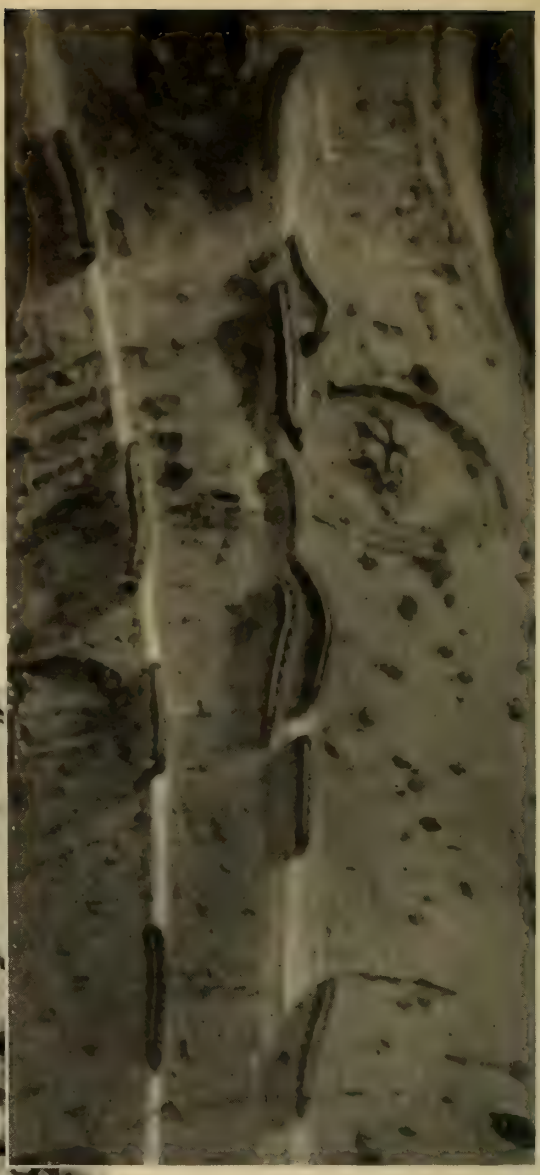
(Above) A silken cocoon spun by a fully grown caterpillar about to pupate

(Above) The same cocoon opened. The larva has molted and become a pupa. The old larval skin may be seen at the lower end of the cocoon

(Above) The adult stage of the tent caterpillar, a brown moth, shown here about four times natural size

Beetles known as caterpillar hunters (Calosoma) are among the caterpillar's natural enemies

(Below) A healthy family of tent caterpillars. A large part of their lives is spent in eating wild cherry leaves and spinning silk



(Above) Tent caterpillars following their silken paths spun between food and rest

Healthy

Diseased

Disease has started in the tent caterpillar family shown at the right. The caterpillars have reached their periodic peak and Nature is restoring her "balance"

(Below) The family has been exterminated by disease

(Below) A tent caterpillar dying of bacterial disease

Before

After

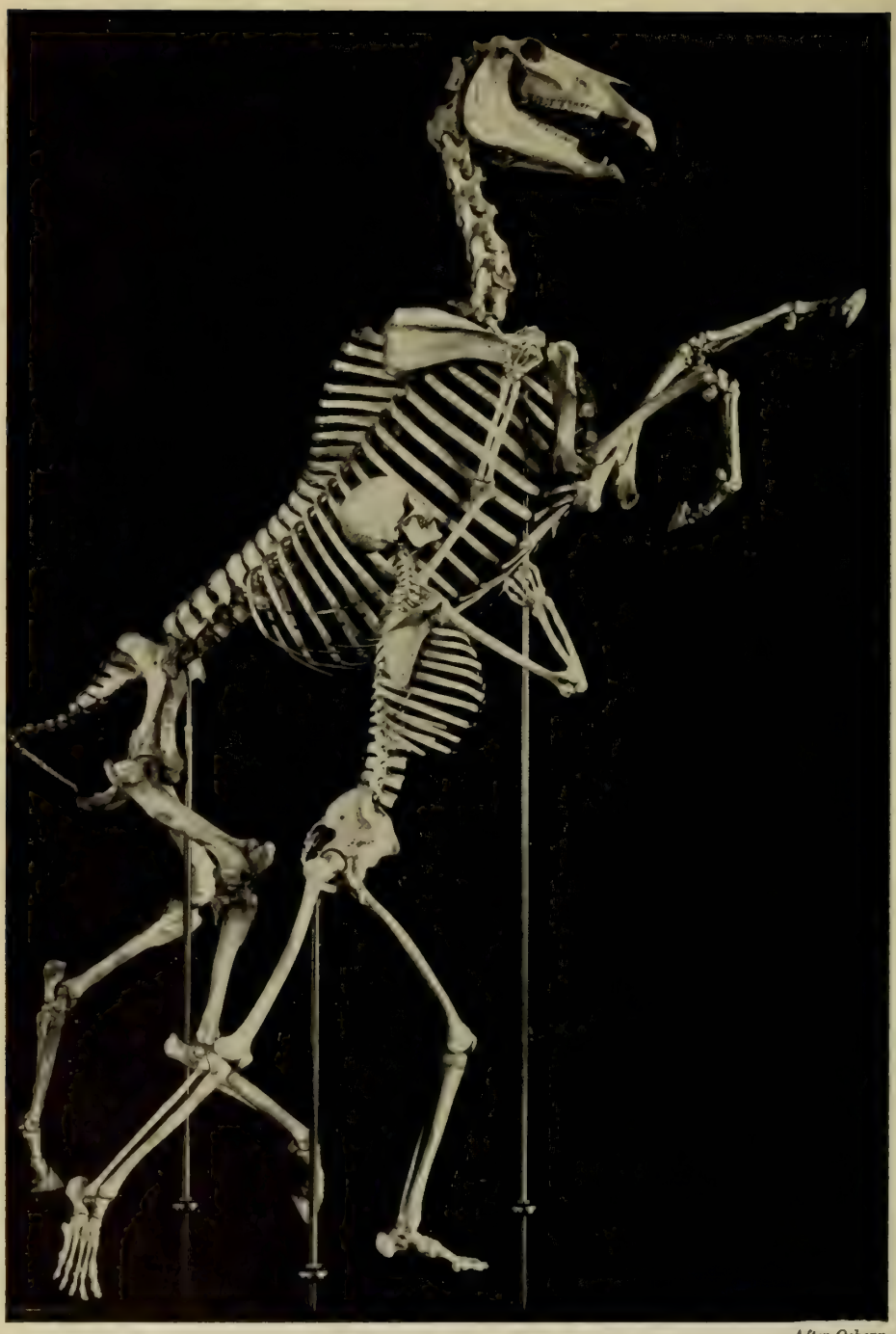
(Top) A wild cherry defoliated by an over population (three nests) of tent caterpillars
(Bottom) Three weeks later. The caterpillars have starved but the wild cherry has not been injured. "Kill, if you wish, the tent caterpillars on your orchard trees and ornamentals, but let Nature take care of the wild trees, and under no circumstance cut down wild cherries"

EVOLUTION OF THE HORSE

BY W. D. MATTHEW AND S. H. CHUBB

GUIDE LEAFLET SERIES No. 36

AMERICAN MUSEUM OF NATURAL HISTORY



After Osborn

SKELETON OF HORSE AND MAN

Mounted by S. H. Chubb for comparative study. Funds for the preparation, a gift of William C. Whitney to the American Museum of Natural History

EVOLUTION OF THE HORSE

IN TWO PARTS

EVOLUTION OF THE HORSE IN NATURE

BY

W. D. MATTHEW

THE HORSE UNDER DOMESTICATION: ITS ORIGIN AND THE STRUCTURE AND GROWTH OF THE TEETH

BY

S. HARMSTED CHUBB

GUIDE LEAFLET SERIES No. 36
SIXTH EDITION, REVISED
NEW YORK, AUGUST, 1932

"* * * the general principles of the hypothesis of evolution lead to the conclusion that the horse must have been derived from some quadruped which possessed five complete digits on each foot; which had the bones of the forearm and of the leg complete and separate; and which possessed forty-four teeth, among which the crowns of the incisors and grinders had a simple structure; while the latter gradually increased in size from before backwards, at any rate in the anterior part of the series, and had short crowns.

And if the horse has been thus evolved, and the remains of the different stages of its evolution have been preserved, they ought to present us with a series of forms in which the number of the digits becomes reduced; the bones of the forearm and leg gradually take on the equine condition; and the form and arrangement of the teeth successively approximate to those which obtain in existing horses.

Let us turn to the facts and see how far they fulfill these requirements of the doctrine of evolution."

Huxley. The Demonstrative Evidence of Evolution.

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PREFACE[1]

Among all the animals of past and present there is none so deserving of our interest and affection as the horse. It is the most useful of the domestic animals, and has played the largest part in the development of civilization. Since the dawn of recorded history the man with the horse has been in the forefront of progress. Whether leading the military civilizations of the past or breaking ground for the industrial civilization of the present the pioneers and leaders of progress have always made large use of this noble animal. It is not too much to say that without his help our ancestors in the Old World might have advanced but little further on the road to civilization than did the inhabitants of the ancient semi-civilized states of Peru and Mexico, where the horse was unknown, and travel, agriculture and military success were limited by the capacity of unaided human strength.

From another point of view the horse is of peculiar interest. It is one of the most perfect machines for swift running that exists among living animals and displays throughout its organization the most exact and finished mechanism adapted to this purpose. It is perhaps the finest example of what nature, acting through millions of years, has been able to accomplish in the way of adapting a large quadruped to speed over long distances, and likewise of the extent to which man, during the few thousand years that he has controlled its development, has been able to improve upon nature, in the sense of adapting it to serve more exactly his own purpose.

The history of this adaptation, continued over millions of years, constitutes the evolution of the horse. Its records consist of the actual skeletons of the successive stages in the development of the race. Buried in ancient river deposits, petrified and preserved to our day in the successive geological strata, they have been discovered and disinterred through the diligent search of scientists during the last fifty years.

This Museum has taken especial interest in the evolution of the horse. The records of this history are most completely preserved in the western United States, and through the liberality of the trustees of the American Museum, and in particular through special funds provided by the late William C. Whitney, by Professor Henry Fairfield Osborn and by other trustees and friends of the Museum, Messrs. James R. Keene, Randolph Huntington, F. K. Sturgis and others, we have obtained, from expeditions, gifts and purchases, many thousand specimens of fossil species, illustrating numerous successive stages in horse ancestry; and a unique series illustrating the diverse breeds of the domesticated animal and the structure and growth of its teeth and skeleton, so marvelously suited to its requirements.

Such parts of the collection as might best serve to illustrate the subject have been placed on exhibition in the hall of fossil mammals and in the West Corridor, on the Fourth Floor. These exhibits show

1. The Evolution of the Horse in Nature
2. The Evolution of the Horse under Domestication

The collections have been gathered together and arranged under the direction and supervision of Professor Henry Fairfield Osborn. Scientific descriptions of parts of the material have been published from time to time by Professor Osborn and his assistants and an extensive monograph on the evolution of the horse is now in preparation.

W. D. Matthew.

American Museum of Natural History, *March*, 1913

[1]Preface to First Edition.

THE EVOLUTION OF THE HORSE.

		Formations in Western United States and Characteristic Type of Horse in Each	Fore Foot	Hind Foot	Teeth
Quaternary or Age of Man	Recent				
	Pleistocene	SHERIDAN	One Toe — Splints of 2nd and 4th digits	One Toe — Splints of 2nd and 4th digits	Long-Crowned, Cement-covered
Tertiary or Age of Mammals	Pliocene	BLANCO			
	Miocene	LOUP FORK	Three Toes — Side toes not touching the ground	Three Toes — Side toes not touching the ground	
	Oligocene	JOHN DAY	Three Toes — Side toes touching the ground; splint of 5th digit	Three Toes — Side toes touching the ground	Short-Crowned, without Cement
		WHITE RIVER			
	Eocene	UINTA	Four Toes		
		BRIDGER			
		WIND RIVER			
		WASATCH	Four Toes — Splint of 1st digit	Three Toes — Splint of 5th digit.	
		PUERCO AND TORREJON			
Age of Reptiles	Cretaceous, Jurassic, Triassic				

Equus

Protohippus

Mesohippus

Protorohippus

Hyracotherium (Eohippus)

Hypothetical Ancestors with Five Toes on Each Foot and Teeth like those of Monkeys etc.

J. Morris S. 1902

Part I. EVOLUTION OF THE HORSE IN NATURE

By W. D. Matthew, Ph.D.
Late Curator of the Department of Vertebrate Palæontology

INTRODUCTION

As a domestic animal the horse is to be found almost everywhere that man can live. He is spread all over the world—from torrid to arctic climates, in all the continents, in remote oceanic islands—he is completely cosmopolitan. But as a wild animal the horse is at present limited to the Old World, and is found there only in the open arid or desert plains of Central Asia and Africa. There are two species in Asia, the Asiatic wild ass (*Equus hemionus*) and the little known Przewalsky horse (*Equus przewalskii*), while in Africa there are the African wild ass (*Equus asinus*) and the several species of zebra (*Equus zebra, Equus burchelli, Equus grevyi*). In the Americas and Australia there are no true wild horses, the mustangs and broncos of the Western Plains and South America being feral (domesticated animals run wild) and descended from the horses brought over from Europe by the early white settlers. When the Spaniards first explored the New World they found no horses on either continent. The Indians were quite unfamiliar with them and at first regarded the strange animal which the newcomers rode, with wonder and terror, like that of the ancient Romans when Pyrrhus and his Greeks brought elephants—"the huge earth-shaking beasts"—to fight against them.

The horse is distinguished from all other animals now living by the fact that he has but one toe on each foot. Comparison with other animals shows that this toe is the third or middle digit of the foot. The hoof corresponds to the nail of a man or the claw of a dog or cat, and is broadened out to afford a firm, strong support on which the whole weight of the animal rests. Behind the "cannon bone" of the foot are two slender little bones, one on each side, called "splint bones." These represent the second and fourth digits of other animals, but they do not show on the surface and there is nothing like a separate toe. So that the horse may be said to be an animal that walks on its middle finger nail, all the other fingers having disappeared.

The teeth of the horse are almost equally peculiar. The molars are long, square prisms which grow up from the gums as fast as they wear off on the crowns. Their grinding surface exhibits a peculiar and complicated pattern of edges of hard enamel between which are softer spaces composed of dentine and of a material called "cement," much like the dentine in quality but formed in a different way. The dentine is formed

on the inside surfaces of the enamel while the tooth is still within the jawbone; the cement is deposited on the outside surfaces of the enamel after the tooth has broken through the jawbone and before it appears above the gums.

Various other peculiarities distinguish the horse from most other animals; some of these are shared by other hoofed animals. The two long bones of the forearm (radius and ulna) are separate in the greater number of animals, but in the horse and in many other hoofed animals, they are consolidated into a single bone (See Fig. 17, p. 27). The same consolidation is seen in the bones of the lower leg (tibia and fibula). (See Fig. 18, p. 28.) The lengthening of the foot and stepping on the end of the toe raises the heel in the horse, as in many other animals, to a con-

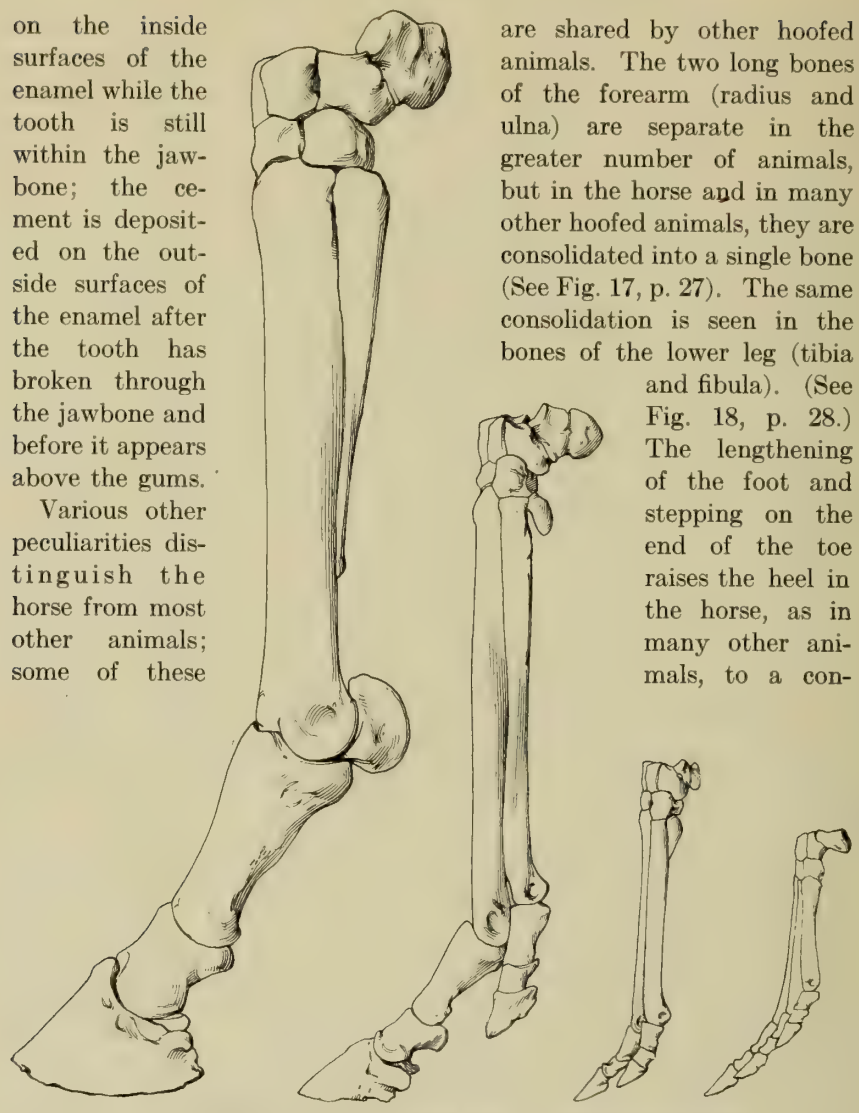


FIG. 2. EVOLUTION OF THE FORE FOOT. PRINCIPAL STAGES

(Right to Left)

1. Four-toed horse *Eohippus*. Eocene Epoch
2. Early three-toed horse *Mesohippus*. Oligocene Epoch
3. Later three-toed horse *Merychippus*. Miocene Epoch
4. One-toed horse *Equus*. Pleistocene Epoch and Modern

All outside views showing the middle and outer digits of the fore foot. In *Eohippus* the two outer toes (digits IV and V) are complete. In *Mesohippus*, digit V is reduced to a small splint and digit IV is notably smaller than the middle digit. In *Merychippus*, digit V is a tiny nodule of bone and digit IV has become very slender in comparison with the middle digit. In *Equus* digit IV is reduced to a long splint, while of the fifth digit no trace remains

siderable height above the ground, where it forms the hock joint, bending backward, as the knee bends forward. In these as in various other ways the legs of the horse are especially fitted for swift running over hard and level ground, just as its teeth are fitted for grinding the wiry grasses which grow on the open plain.

The zebra and the ass have the same peculiar structure of teeth and feet as the domestic horse, and differ only in the color of the skin, proportions of various parts of the body, etc.

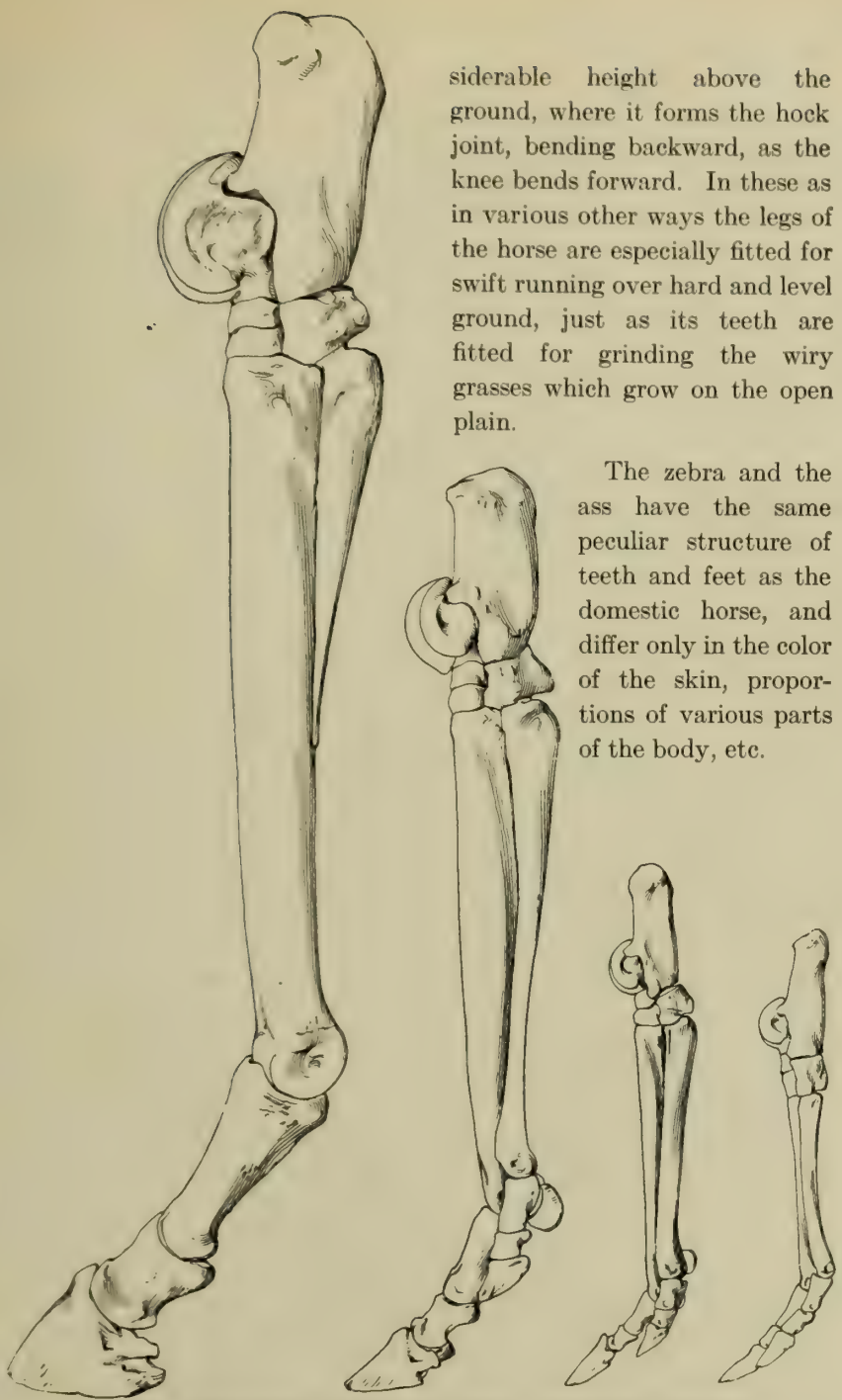


FIG. 3. EVOLUTION OF THE HIND FOOT. PRINCIPAL STAGES

(Right to Left) 1, *Eohippus*. Eocene Epoch; 2, *Mesohippus*, Oligocene; 3, *Merychippus*, Miocene; 3, *Equus*, Pleistocene and Modern

Outer views showing middle and outer digits. Note progressive reduction of side toe (digit IV) from a well developed digit to a splint bone

FOSSIL HORSES OF THE AGE OF MAN

THE Age of Man, or Quaternary Period, is the last and by far the shortest of the great divisions of geological time. It includes the Great Ice Age or Glacial Epoch (Pleistocene), when heavy continental glaciers covered the northern parts of Europe and North America, and the Recent Epoch, of more moderate climate during which civilization has arisen.

In the early part of the Quaternary Period, wild species of horse were to be found on every continent except Australia. Remains of these true native horses have been found buried in strata of this age in all parts of the United States, in Alaska, in Mexico, in Ecuador, Brazil and Argentina, as well as in Europe, Asia and Africa. All these horses were much like the living species and most of them are included in the genus *Equus*. Mr. J. W. Gidley, in charge of the American Museum expedition in northern Texas, discovered in 1899 a number of more or less complete skeletons of a species of fossil horse, *Equus scotti*, in an old river deposit on Rock Creek in Donley County. These are the most complete specimens known of the extinct horses which inhabited this country at the beginning of the Ice Age. A mounted skeleton and several skulls have been placed on exhibition, and their near resemblance to the modern animal appears at a glance. The difference from the domestic horse is chiefly in proportions: the skull is shorter with deeper jaws, the legs rather short and the feet small in proportion to the body. In these characters this fossil horse resembles an overgrown zebra rather than a domestic horse. We know nothing of its coloring. It may have been striped, and in this case would have been very zebra-like; but there are some reasons for believing that it was not prominently striped. The bones are petrified, brittle and heavy, the animal matter of the bone having entirely disappeared and having been partly replaced by mineral matter. They are not much changed in color however, and are so perfectly preserved that they look almost like recent bone.

All the remains of these native horses which have been found in America have been petrified more or less completely. This means that they have been buried for many thousands of years, for true petrifaction is an exceedingly slow process. This condition serves as an easy means of distinguishing them from bones of the domestic horse, found buried in the earth. These cannot in any case have been buried for more than three or four centuries, and have not had time to petrify.

Remains of these fossil horses from various parts of the United States are shown in the counter cases. One very rich locality is on the Niobrara River in Nebraska, another is in central Oregon. Many separate teeth and bones have been found in the phosphate mines near

Charleston, South Carolina; other specimens have come from central Florida, from southern Texas, Arizona, Kansas, Louisiana and even from Alaska. They are, in fact, so often found in deposits of rivers and lakes of the latest geological epoch (the Pleistocene) that the formation in the western United States has received the names of "Equus Beds."

In South America, in strata of the Pleistocene Epoch, there occurs, besides several extinct species of the genus *Equus*, the *Hippidium*, a peculiar kind of horse characterized by very short legs and feet, and some peculiarities about the muzzle and the grinding teeth. The legs were hardly as long as those of a cow, while the head was as large as that of a race horse or other small breed of the domestic horse.

All these horses became extinct, both in North and South America. Why, we do not know. It is very probable that man—the early tribes of prehistoric hunters—played a considerable part in their disappearance, not indeed by killing them all off directly, but by continual hunting and chasing, driving them from the best feeding-grounds and interfering with their habits and opportunities for grazing. This persecution would tend to reduce their numbers and vigor, and be the prelude to their extinction. The competition with the bison, which had recently migrated to America, may also have made it more difficult than formerly for the American horse to get a living. And finally, some epidemic disease or prolonged season of drought may have exterminated the race. Whatever the cause, the horse had disappeared from the New World when the white man invaded it (unless a few individuals still lingered on the remote plains of South America), and in his place the bison had come and spread over the prairies of the North.

Fossil horses are equally common in the Pleistocene formations of the Old World. They have been found in all parts of Europe and Asia, in North and South Africa, but not in Australasia, the East Indies or Madagascar. In Central Asia, two wild races persist to the present day; others were domesticated by man in the earliest times, and their use in Chaldea and Egypt for draft and riding is depicted in the ancient mural paintings. In Africa the larger species became extinct in prehistoric times, as in America, but the smaller zebras still survive in the southern part of the continent (one species, the quagga, abundant fifty years ago, is now extinct), and the African wild ass is found in the fauna of the northern part. The wild horse of prehistoric Europe, a small race, short-legged and shaggy-haired, was domesticated by man, a fact that is

[1]They are probably derived from three different wild sources which Professor Cossar Ewart has called the Forest Type of Northern Europe, the Steppe Type of Northern Asia, resembling the Przewalsky horse, and the Plateau or Desert Type of Northern Asia, resembling the Arabian.—Henry Fairfield Osborn.

known from the rude drawings scratched on bone or ivory by men of the Neolithic or Polished Stone Age. But the domesticated horses now in use are derived chiefly from the Asiatic and African species although it is probable that in some breeds there is a considerable strain of this shaggy, short-legged European race. The domesticated ass is a descendant of the wild ass (*Equus asinus*) of North Africa.

THE EVOLUTION OF THE HORSE

THE history of the evolution of the horse through the Tertiary Period of Age of Mammals affords the best known illustration of the doctrine of evolution by means of natural selection and the adaptation of a race of animals to its environment. The ancestry of this family has been traced back to near the beginning of the Tertiary without a single important break. During this long period of time, estimated at nearly three millions of years, these animals passed through important changes in all parts of the body, but especially in the teeth and feet, adapting them more and more perfectly to their particular environment, namely the open plains of a great plateau region with their scanty stunted herbage, which is the natural habitat of the horse.

In the series of ancestors of the horse we can trace very step in the evolution of those marked peculiarities of teeth and feet which distinguish the modern animal from an ancestor which so little suggests a horse that when its remains were first found forty years ago, it was named by the great palæontologist Richard Owen, the *Hyracotherium* or "coney-like beast." Its relation to the horse was not at that time suspected by Professor Owen, and was recognized by scientific men only when several of the intermediate stages between it and its modern descendant had been discovered. On the other hand this first ancestor of the horse line is very difficult to distinguish from the contemporary ancestors of tapirs and rhinoceroses, and indicates how all the modern quadrupeds have diverged from a single type, each becoming adapted to the needs of its especial mode of life.

FOUR-TOED HORSES

THE earliest known ancestors of the horse were small animals not larger than the domestic cat, with four complete toes on each fore foot and three on each hind foot. There is reason to believe that still more ancient ancestors of this and all other mammals had five toes on each foot. In the fore foot of the earliest known stage there *may* have been a small, slender rudiment representing the missing first digit or thumb, which no longer appeared on the surface of the foot,[1] while in the

[1]It is shown in Marsh's well known diagram; but there is no conclusive evidence of its presence on any specimen yet found.

hind foot there is a similar rudiment representing the outer or fifth digit, and also a tiny remnant of the innermost or first digit. The proportions of the skull, the short neck and arched back and the limbs of moderate length, were very little horselike—recalling on the contrary, some modern carnivorous animals, especially the civets (*Viverridæ*). The teeth were short-crowned and covered with low rounded knobs of enamel, suggesting those of monkeys and of pigs or other omnivorous animals, but not at all like the long-crowned complicated grinders of the horse.

Commencing with the *Hyracotherium*, twelve stages have been recognized from as many successive formations, showing the gradual evolution of the race into its modern form, and each stage is characteristic of its particular geological horizon. Some of the stages have been found in several parts of the world, but by far the most complete and best known series comes from the Tertiary Badlands of the western United States. Besides the main line of descent which led into the modern horses, asses and zebras, there were several collateral branches which have left no descendants. Of some stages all parts of the skeleton have been found; of others only the jaws, or jaws and feet, are known. We can mention only the more important stages.

1 and 2[1]. **Hyracotherium** and **Eohippus** LOWER EOCENE. The *Hyracotherium* is the most primitive stage known, but only the skull has been found, so that it has not been determined exactly what the feet were like. The teeth display six rounded knobs or cusps on the upper molars and four on the lower ones, and these are just beginning to show signs of fusing into cross-crests. The premolar teeth have only one main cusp, except the third and fourth premolars (next the molars) in each jaw, which have two and three, respectively. The only specimens which have been found were in the London Clay or Lower Eocene of England and are preserved in the British Museum.

Fig. 4. *Eohippus.* Lower Eocene. Upper teeth, natural size. Short-crowned teeth, no cement, premolars simpler and smaller than molars

The *Eohippus* is much better known. It comes from the Lower Eocene of Wyoming and New Mexico, and is very like the *Hyracotherium*[2] except that in some species the molar teeth have the cusps more clearly fusing into cross-crests; the last premolars is beginning to look like one of the true molars. The fore foot of this animal has four complete toes. The hind foot has three complete toes and the splints of the first and fifth digits can still be detected in some species. A skeleton of *Eohip-*

[1]These numbers refer to the stages in the direct line of descent of the modern horse.
[2]It is doubtful whether it is a distinct genus.

pus was found by Dr. J. L. Wortman in 1880 in the Wind River Badlands of Wyoming, and was described by Professor Cope in 1885. It was until recently the only skeleton known of a four-toed horse, and is well known to the scientific world. It was purchased by the trustees of the American Museum in 1894 and is now on exhibition.

A second skeleton found by the Museum expedition of 1910, is of a larger species, but not advanced in any other respect. It is mounted in a grazing attitude, and probably represents the general appearance of *Eohippus* more truly than the Cope skeleton. A third imperfect skeleton secured in 1911 is interesting as it shows the tiny splint bone of the inner digit of the hind foot, indicated by facets in other specimens but not actually found before. Crushed skulls, jaws and fragments of skeleton bones of thousands of individuals have been found in the Lower Eocene formations.

3. **Orohippus.** Middle Eocene. In this animal the splints of the first and fifth digits of the hind foot have disappeared, but there are still four complete and usable toes in the fore and three in the hind foot. The crests on the molars are a little clearer and the last premolar has become almost like the molars, while the next to the last premolar is partially molariform. A skeleton of *Orohippus*, discovered by Mr. Walter Granger of the Museum expedition of 1906, in the Bridger Badlands of southwestern Wyoming, is exhibited next to the *Eohippus* skeleton. It shows an animal of the size of a small dog and proportioned much like the breed known as the *whippet*.

The *Orohippus* was of about the same size and proportions as some of the pigmy antelopes or duikerboks (*Cephalophus*), which live in the open forests and brush country of East and South Africa, and have gained their name from the quickness with which they can dive or "duck" into the tall grass and jungle on the approach of danger.

Fig. 5. *Orohippus.* Middle Eocene. Upper teeth, natural size. Short-crowned teeth, no cement, fourth premolar like molars

Fig. 6. *Epihippus.* Upper Eocene. Upper teeth, natural size. Short-crowned teeth, no cement, third and fourth premolars like molars

4. **Epihippus.** Upper Eocene. Of this stage of the evolution of the horse only incomplete specimens have been found. The molar teeth have the once round cusps almost completely converted into crescents and crests, while another tooth of the premolar series has become like the molars. The toes are still four in

the fore foot and three in the hind foot, but the central toe in each foot is becoming much larger than the side toes.

Palæotherium and *Plagiolophus* of the Upper Eocene of Europe form a side branch of the horse line. They were very abundant in Europe, but have not been found in the New World. One of these animals was thought by Professor Huxley to be a direct ancestor of the horse, but it is now considered to be merely a collateral relative. Some species of *Palæotherium* were of large size, equal to a tapir. They were first described in the year 1804 by the celebrated Baron Cuvier from remains found in the gypsum quarries of Montmartre, Paris.

THREE-TOED HORSES

5, 6, and 7. **Mesohippus** and **Miohippus.** OLIGOCENE. In this stage there are three toes on each foot, and a splint representing the fifth digit of the fore foot of the Eocene ancestors. The middle toe is now much larger than the side toes, which bear very little of the weight of the animal. Three of the premolars have now become entirely like the molar teeth, the crests on the crown are completely formed, and the outside crest in the upper molars has taken the shape of two crescents. In the Lower and Middle Oligocene are found several species of *Mesohippus* mostly of the size of the coyote, represented by two mounted skeletons, and various skulls, jaws and feet. In the Upper Oligocene occurs *Miohippus intermedius* as large as a sheep, of which a fine skeleton is exhibited in the pavilion case. Several other species of larger or smaller size are represented by skulls and jaws.

The series of skeletons in the pavilion case shows in a very striking way the steady increase in size from the Lower Eocene to the Upper Oligocene, and the reduction of the side toes with concentration of the weight upon the middle toe.

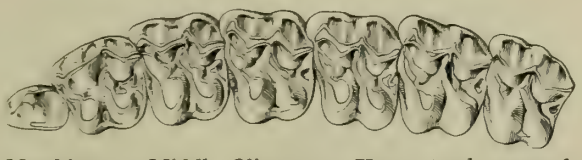
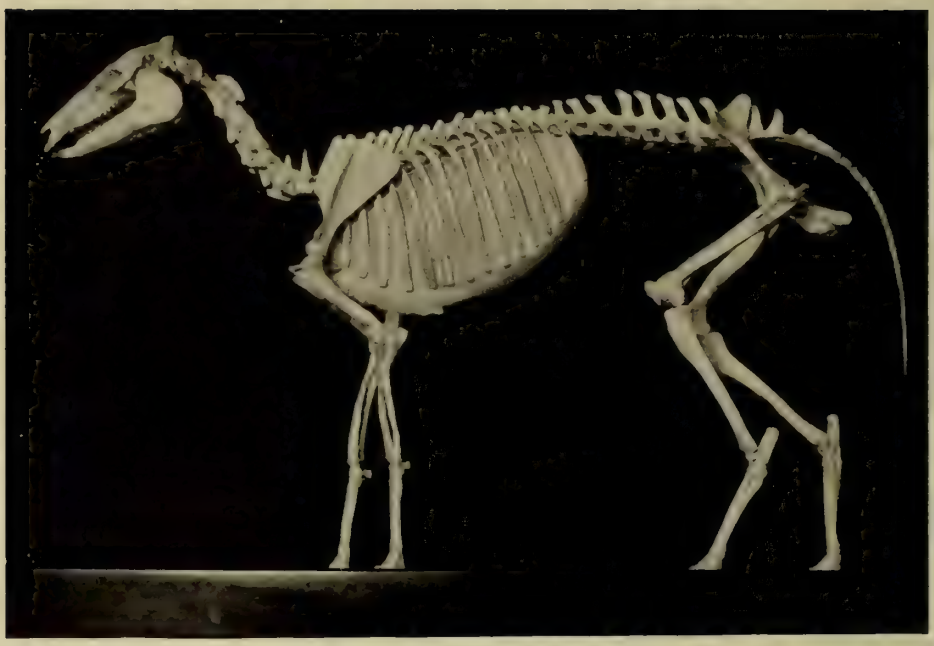


Fig. 7. *Mesohippus.* Middle Oligocene. Upper teeth, natural size. Short-crowned teeth, no cement, second, third and fourth premolars like molars.

8*a*. **Anchitherium** and **Hypohippus.** MIOCENE. *Anchitherium* has been found only in Europe, and is still very incompletely known. It is much like *Mesohippus*, but is larger and has the crests of the teeth somewhat higher and more complete. *Hypohippus* is off the direct line of descent; its teeth are like those of *Anchitherium*, by which name it has



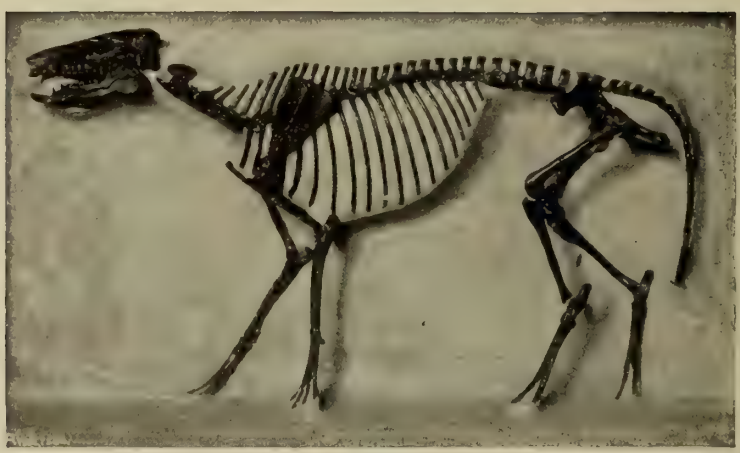
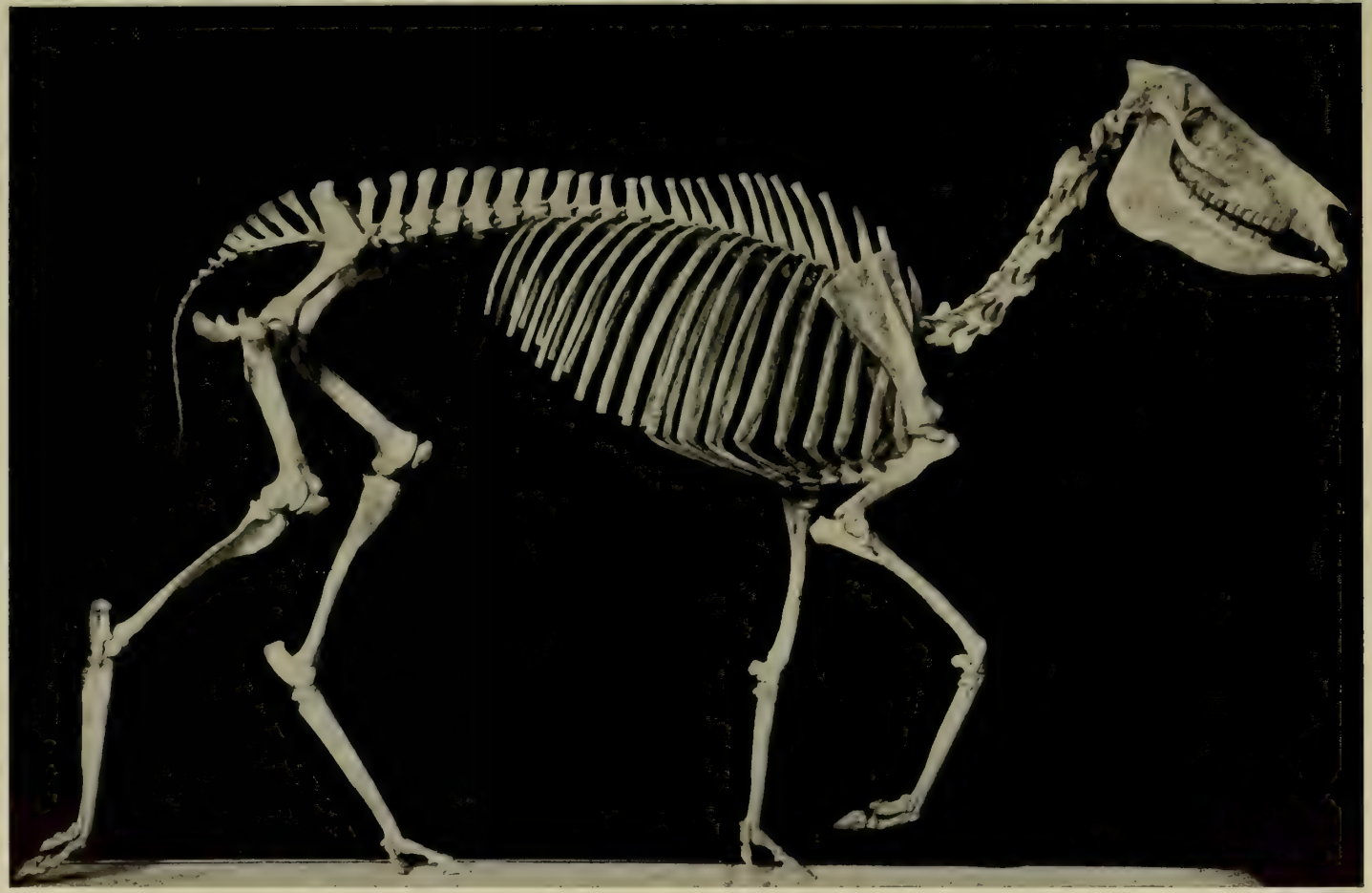


Fig. 8. Little three-toed horse (*Mesohippus bairdi*) from the Middle Oligocene of South Dakota. American Museum No. 1492

Four-toed horse (*Eohippus venticolus*) from the Lower Eocene of Wyoming, American Museum No. 4832



After Osborn

FIG 9. SKELETON OF THREE-TOED HORSE (*Hipparion whitneyi*)
From the Upper Miocene of South Dakota. American Museum No. 9815

been generally called, but the animal was much larger, equalling a Shetland pony in size. A complete skeleton of the *Hypohippus* (shown in wall case) was found near Pawnee Buttes, Colorado, in 1901 by Mr. Barnum Brown, of the Whitney expedition.

Hypohippus first appears in the Middle Miocene, and survives along with more advanced stages of the three-toed horses. It is a larger and more heavily proportioned animal; the wide flat hoofs and strong side toes enabled it to tread on soft ground, and the teeth are fitted for browsing rather than grazing. Hence Professor Osborn considers it as adapted for a forest life, and has named it the "three-toed forest horse." The restoration illustrates this supposed habitat and adaptation.

8 and 9. **Parahippus.** MIOCENE. In *Parahippus* the tooth-crests are somewhat higher, and the transverse ridges on the upper molars are beginning to change shape so as to become a second pair of crescents inside the outer pair. In the valleys between the cross-crests and on the sides and base of the crown, a deposit of cement appears on the surface of the enamel. In some species there is a considerable amount, but usually it is a very thin coat. There is no cement on the milk teeth. The feet show a decided advance over the preceding stages, the side toes are very slender, and no longer touch the ground. The fifth digit of the fore foot is in some species a very short small splint, in others it is still further reduced to a little irregular nodule of bone. This stage first appears in the Lower Miocene, and several skulls and incomplete skeletons have recently been obtained from formations of this age. It survived however, although rare, as a contemporary of the later three-toed horses.

Fig. 10. *Parahippus.* Lower Miocene. Upper teeth, one-half natural size. Short-crowned teeth, traces of cement. The teeth are larger than in *Mesohippus* [the drawing is on a smaller scale], the crowns a little longer, and the inner "crests" begin to show the change to "crescents"

10. **Merychippus.** MIDDLE MIOCENE. This stage marks the transition between the older short-crowned teeth without cement, and the long-crowned heavily cemented teeth of the later stages. The permanent molars are intermediate in length of crown, and quite heavily cemented, but the milk molars are short-crowned and have little or no cement; they are not easily distinguishable from those of *Parahippus.* The side toes are slender and no longer reach the ground; in some species they are almost reduced to splints. *Merychippus* is common in the Middle and later Miocene, and many skulls, jaws and incomplete skeletons are contained in our collections, some of which are placed on exhibi-

tion. These very perfect specimens show a vestige of the fifth digit in the fore foot still preserved as a tiny nodule of bone at the back of the wrist.

11. **Hipparion, Protohippus** and **Pliohippus.** Upper Miocene and Pliocene. These three closely related genera represent the latest stage of three-toed horses, before the side toes were reduced to splints. The teeth are long-crowned, both milk and permanent teeth being heavily cemented, and the side toes are extremely slender. They first appear in the Upper Miocene, probably directly descended from Middle Miocene species of *Merychippus*, and are best represented by the beautifully preserved skeleton of *Hipparion whitneyi* from Little White

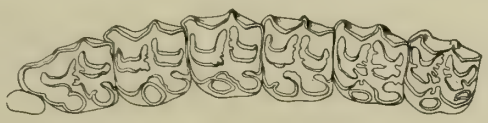


Fig. 11. *Merychippus.* Middle Miocene. Upper teeth, one-half natural size. Moderately long-crowned teeth, well cemented

River, South Dakota, found by Mr. H. F. Wells of the Whitney expedition of 1902. This species, except for the very large head, had the graceful and slender proportions of the antelopes but in *Protohippus* and especially in *Pliohippus* the skeleton approached more nearly the stockier proportions of the modern horses. The *Hipparion whitneyi* is regarded by Professor Osborn as fitted to live in a semi-desert country, and in contrast to the *Hypohippus*, is called the "three-toed desert horse." The restoration depicts this adaptation and environment.

In this stage the crowns of the upper molars have become much longer, the two pairs of crescents on the upper molars are complete, with two half-separated cusps within the inner pair. And the valleys between the crests are completely filled with cement, so that with the wear of the teeth the edges of hard enamel are backed inside by dentine and outside by cement. In this way the surface of the tooth has a series of enamel ridges always projecting a little above the grinding surface, because the softer material on each side wears down into hollows, yet never breaking off, because they are braced so thoroughly on each side. This is a very efficient instrument for grinding hard grasses. The crowns of the teeth in these Miocene horses are by no means as long as in the modern horses; they must therefore have worn more slowly or worn out at an earlier age.

The feet in these genera have but one toe touching the ground. The side toes (second and fourth digits) are complete, but much more slender

than in the earlier stages and are apparently useless, as they cannot reach the ground. In some species they have almost disappeared. The fore feet of these Upper Miocene horses still retain the tiny nodule of bone at the back of the "knee" (the joint that corresponds to the wrist of a man), which is the last remnant of the fifth digit possessed by their remote ancestors.

Hipparion is common in Europe and Asia as well as in North America, but *Protohippus* and *Pliohippus* are not found in the Old World.

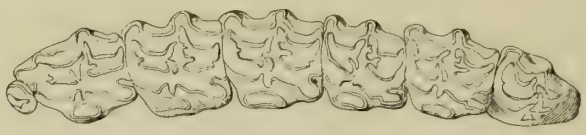


Fig. 12. *Hipparion.* Lower Pliocene. Upper teeth one-half natural size. Long-crowned teeth, heavily cemented

ONE-TOED HORSES

12. **Pliohippus.** Pliocene. In some species of *Pliohippus*, although not in all, the side toes are still further reduced to long slender splint-like bones which are enclosed within the skin, the little separate toes having disappeared. These are the first of the One-toed Horses. The splint is nearly as long as the cannon bone, much longer than it is in *Equus*. Two fine skeletons of *Pliohippus* in the Museum collections (*P. leidyanus*, adult, and *P. lullianus*, young) admirably illustrate this stage.[1] They are of somewhat later geologic age than the *Hipparion* skeleton, and nearer to the modern horse in size, proportions and various details of structure. Yet they are so much like other species of *Pliohippus* in which the side toes are still complete that both are placed in the same genus. *Pliohippus* is therefore transitional from the three-toed to the one-toed stage. It may be that some of the later species of *Hipparion* were also one-toed, but at present there is no proof of it.

13. **Plesippus.** Pliocene. This stage, recently distinguished, is the long missing transition between *Pliohippus* and *Equus*. The side toes are even more reduced than in *Pliohippus*. They were splints buried beneath the skin, but are still a little longer than in Equus. The fifth

[1] *Pliohippus* was described in 1874 by Professor Marsh, as a one-toed ancestor of the horse; but his specimens do not prove that the side toes were certainly absent. These two skeletons found in 1917 by H. J. Cook and 1916 by E. R. Troxell show this conclusively, and we are therefore able to distinguish them as a separate stage in the evolution of the horse. In previous editions of this guide, 1903, 1905, 1913, this stage was not distinguished, as conclusive proof from specimens had not been found.

digit and the trapezium are still present as tiny nodules of bone, but smaller than in *Pliohippus*. Similar characters intermediate between the first one-toed horses and the modern horse occur throughout the skeleton. The tooth pattern is nearly as in *Pliohippus*, but approaches *Equus* in having longer and less curved crowns. This stage is represented in our collection by a fine skeleton of *Plesippus simplicidens* found in the Panhandle of Texas in 1924 by Matthew and Simpson.[1]

14*a*. **Equus.** Pleistocene and Recent. In this stage, that of the modern horse, the side toes have entirely disappeared and are represented by moderately long splints on the fore and hind foot. No trace remains on the fore foot of the little nodule which in previous stages represented

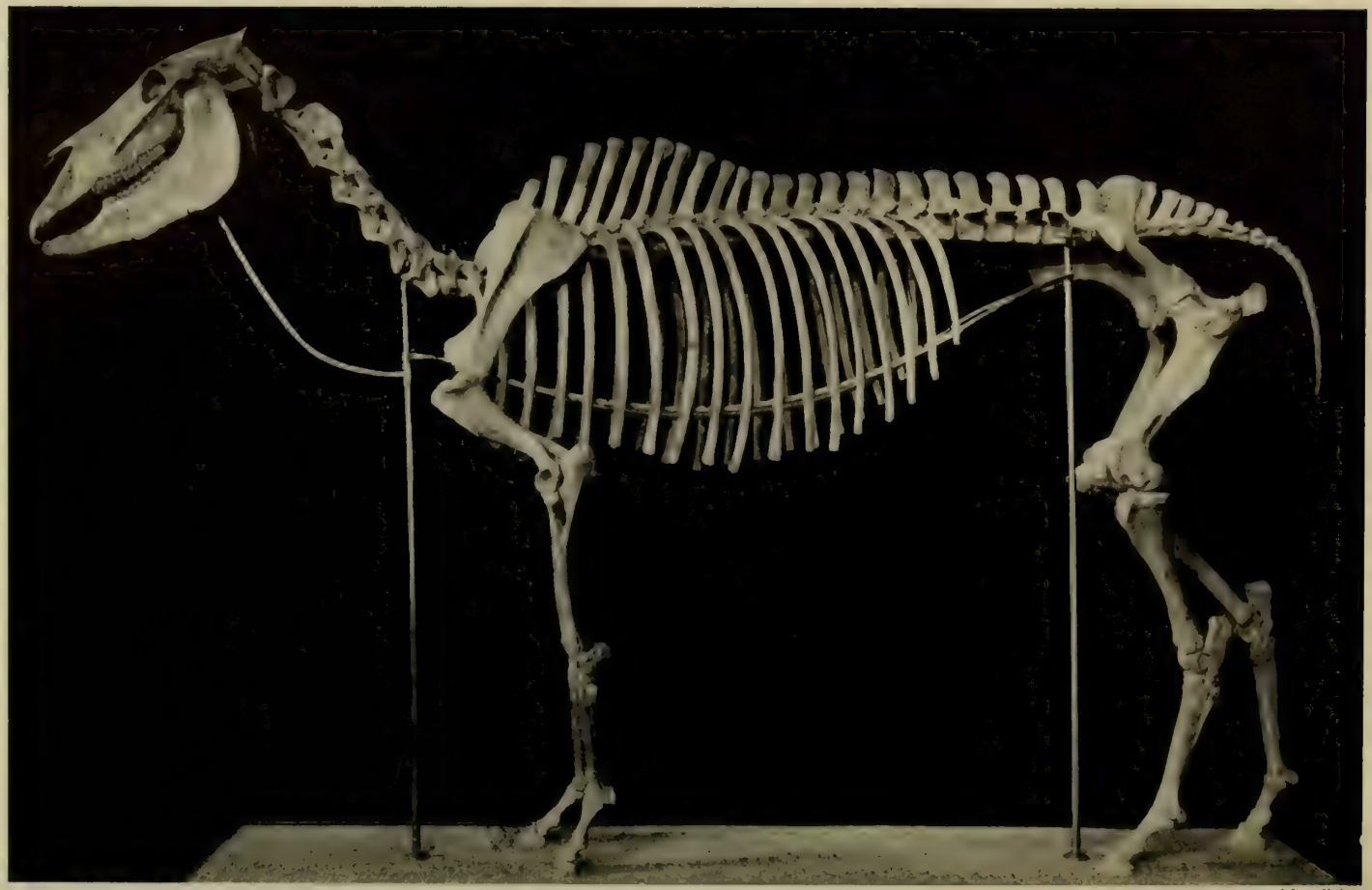
Fig. 13. *Equus*. Pleistocene. Upper teeth, one-half natural size. Very long-crowned teeth, heavily cemented

the fifth digit, while on the inner side of the wrist the "trapezium," always present in the earlier stages, but progressively smaller, is now generally absent entirely. The crowns of the teeth are much longer, and of the two half-separated inner columns on the upper molars, one has disappeared, the other has increased in size and changed in form. The skull has lengthened and the animal is much larger.

It is well represented among the fossil horses by the skeleton and skulls of *Equus scotti* already noticed and by skulls, jaws and teeth of other species from various localities.

14*b*. **Hippidium, Onohippidium.** Pleistocene. South America. The feet are like those of *Equus*, except that they are short and stout. The teeth are like those of *Pliohippus*, from which it is supposed to be descended. The skull is large and long with very long slender nasal bones. A cast of the skeleton of *Hippidium* presented by the Museo Nacional of Buenos Ayres, Argentine Republic, is on exhibition, also a skull cast of *Onohippidium*.

[1]This species was previously known from isolated teeth and this find first proved that it represents a separate generic and evolutionary stage and that *Equus* is derived through this stage from *Pliohippus* rather than from Hipparion. In 1929–31, under the direction of the late Dr. J. W. Gidley, the United States National Museum discovered a wonderful series of skulls and skeletons of this genus (*P. shoshonensis*) on the old Oregon trail in Idaho.



After Osborn

FIG. 14. SKELETON OF EXTINCT AMERICAN HORSE (*Equus scotti*)
From Lower Pleistocene of Texas. American Museum No. 10608

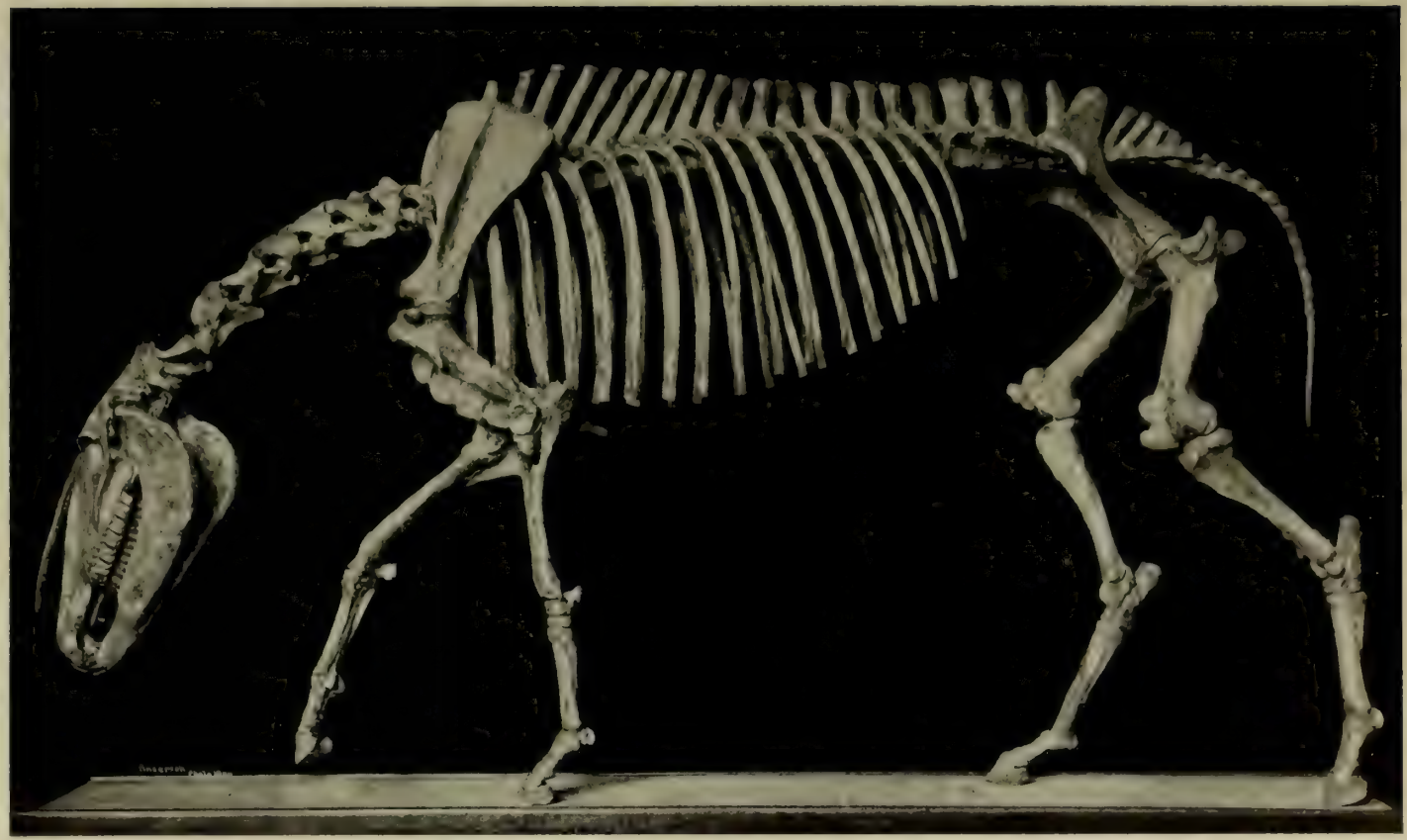


FIG. 15. SKELETON OF SHORT-LIMBED HORSE (*Hippidium*)
From Pleistocene of Argentine Republic. From a cast in the American Museum

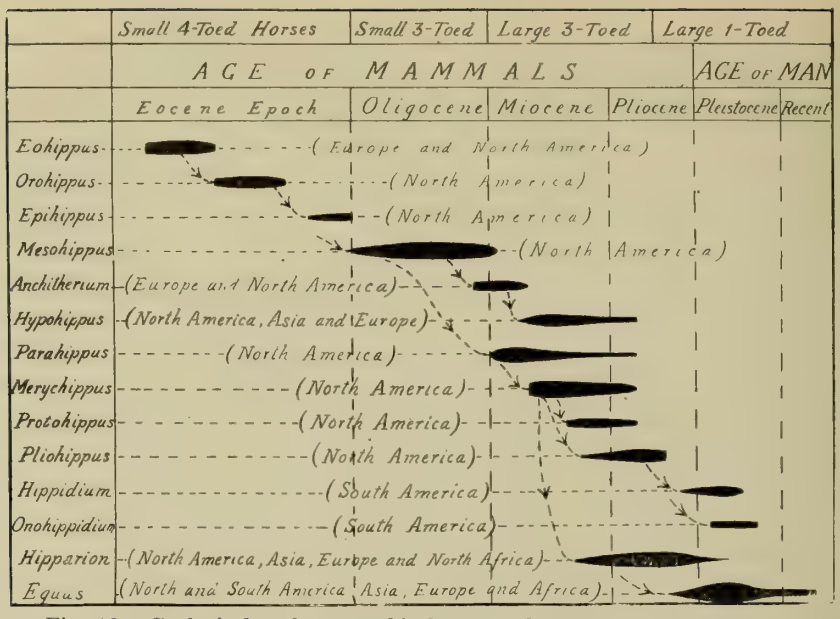


Fig. 16. Geological and geographical range of ancestors of the horse. The position and length of the heavy black lines show the occurrence and range of each genus in the successive geologic epochs, while the thickness of the lines indicates relative abundance. The dotted connecting lines with arrows indicate the genealogy

CONCLUSIONS

THESE are the principal stages in the evolution of the modern horse from the little four-toed *Eohippus*. Intermediate between them are numerous minor stages, the earlier species of each genus being more primitive, the later species more advanced. The series of upper molar teeth shown in Figs. 19–20 show no wide differences from one stage to the next. But between most of them several intermediate species are known. This gradual change is seen not merely in one or few selected parts, but in every bone, every tooth, every portion of the skeleton. Elsewhere in the hall may be found similar although less complete series leading up from animals very close to *Eohippus* into the modern tapir and rhinoceros. The conclusion is unavoidable that horse, rhinoceros and tapir, three races widely different today, are derived through progressive changes from a common ancestral type. New *species* may have appeared suddenly, but the race in its broader lines is the product of gradual evolution, and diverse races may be traced back to a more ancient common stock.[1]

[1]Scientific criticisms of "Darwinism" are concerned with the way in which new species have appeared, whether by infinitesimal gradations or by finite "mutations," appreciable although usually small steps. The broader lines of evolution are not affected by these criticisms.

MEANING OF THE CHANGE IN FEET AND TEETH

ALONG with the disappearance of the side toes in the evolution of the horse there is a considerable increase in the proportionate length of the limbs, and especially of the lower part of the leg and foot. The surfaces of the joints, at first more or less of the ball-and-socket kind which allows free motion of the limb in all directions, become keeled and grooved like a pulley-wheel, permitting free motion forward and backward, but limiting the motion in all other directions and increasing considerably the strength of the joint. By this means the foot is made more efficient for locomotion over a smooth regular surface, but less so for traveling over very rough ground, and it becomes of little use for striking or grasping or the varied purposes for which the feetof polydactyl animals are used.

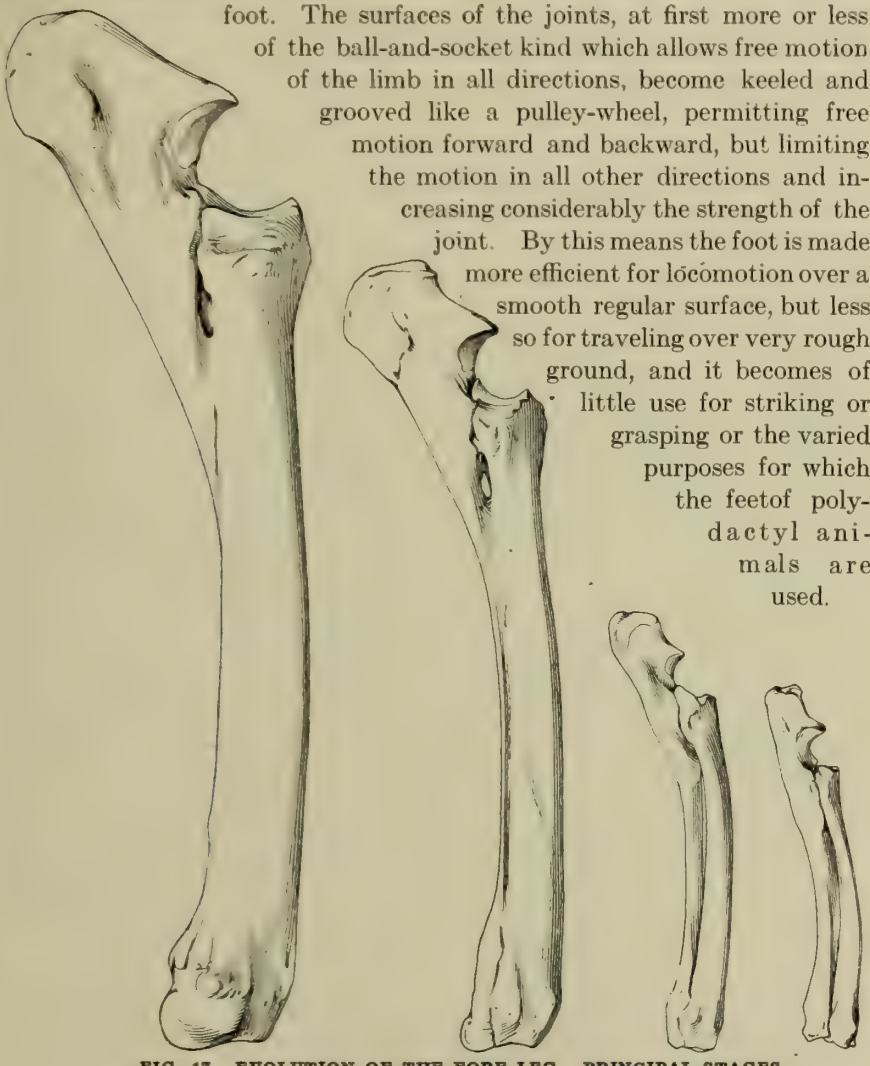


FIG. 17. EVOLUTION OF THE FORE LEG. PRINCIPAL STAGES

Equus, Merychippus, Mesohippus, Eohippus

In the four-toed horses (*Eohippus*) the radius and ulna are separate and their shafts of about equal size. In the earlier three-toed horses (*Mesohippus*) the ulna is separate but its shaft considerably reduced. In the later three-toed horses (*Merychippus*) the ulna is partly consolidated with the radius and its shaft is reduced to a thin thread. In the one-toed horses (*Equus*) the ulna is more completely consolidated with the radius and its shaft has entirely disappeared

The increased length in the lower leg and foot increases the length of the stride without decreasing its quickness. The heavy muscles of the leg are chiefly in the upper part, and to increase the length of the lower part changes the centre of gravity of the limb very little. Consequently the leg swings to and from the socket nearly as fast as before, since in an ordinary step the action of the leg is like that of a pendulum, and the speed of the swing is regulated by the distance of the centre of gravity from the point of attachment, as that of a pendulum is by the height of the bob. To increase the length of lower leg and foot therefore gives the animal greater speed; but it puts an increased strain on the ankles and toe-joints, and these must be strengthened correspondingly by converting them from ball-and-socket joints to "ginglymoid" or pulley joints. Additional strength, likewise at the

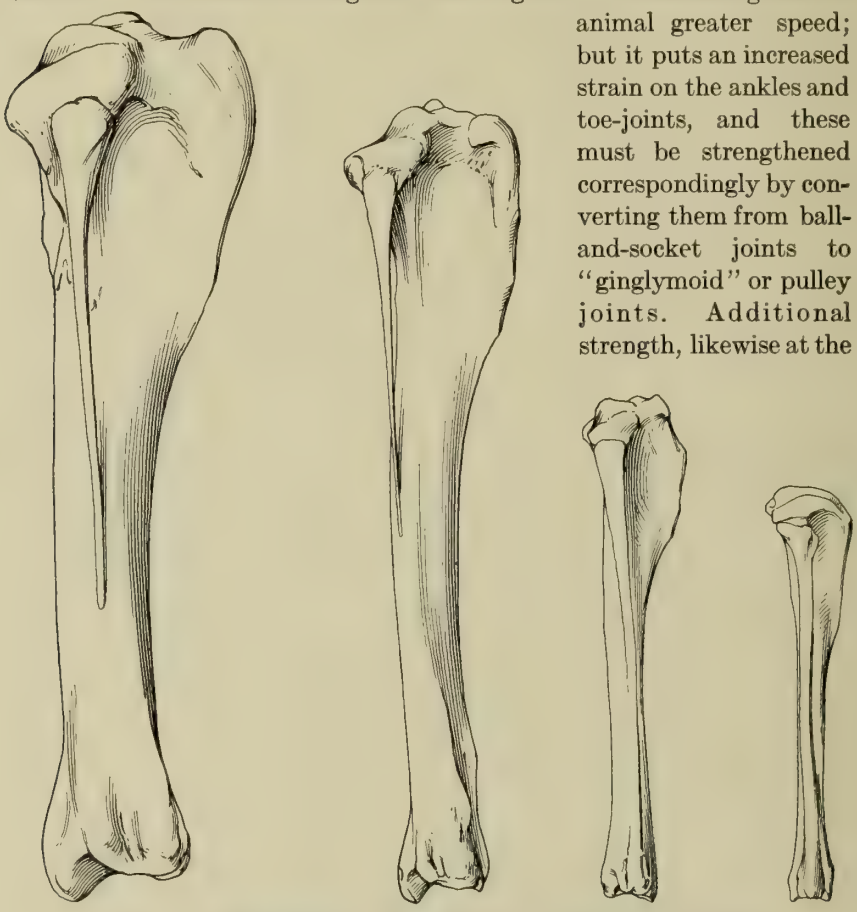
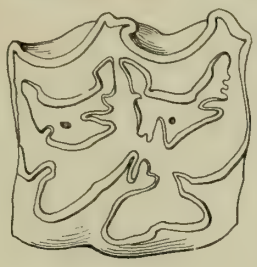


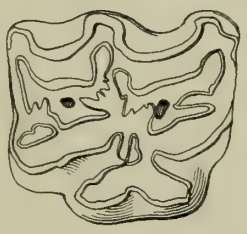
FIG. 18. EVOLUTION OF THE HIND LEG. PRINCIPAL STAGES

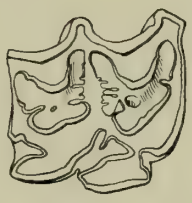
Equus, Merychippus, Mesohippus, Eohippus

In the four-toed horses (*Eohippus*) the fibula is complete and separate from the tibia. In the earlier three-toed horse (*Mesohippus*) it is very slender, and fused with the tibia from about the middle of the shaft down. In the later three-toed horses (*Merychippus*) the shaft of the fibula is incomplete and both ends are fused with the tibia. In the one-toed horses (*Equus*) the lower end is more thoroughly united so as to be indistinguishable from the tibia

FIG. 19. EVOLUTION OF THE TEETH. EARLIER STAGES. Second Upper Molar (Read up). (1) *Eohippus* Lower Eocene; (2) *Orohippus*, Middle Eocene; (3) *Epihippus*, Upper Eocene; (4) *Mesohippus montanensis*, Lower Oligocene; (5) *Mesohippus bairdi*, Middle Oligocene; (6) *Miohippus* Upper Oligocene; (7) *Parahippus*, Lower Miocene







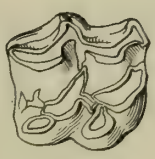


FIG. 20. EVOLUTION OF THE TEETH. LATER STAGES. Second Upper Molar (Read up). (8) *Merychippus*, Middle Miocene; (9) *Hipparion*, Upper Miocene; (10) *Equus stenonis*, Pliocene; (11) *Equus complicatus*, Pleistocene; (12) *Equus caballus*, the modern horse

expense of flexibility, is obtained by the consolidation of the two bones of the forearm (ulna and radius) and of the leg (tibia and fibula) into one, the shaft of the smaller bone practically disappearing, while its ends become fused solidly to its larger neighbor. The increase in length of limb renders it necessary for the grazing animal that the head and neck should increase in length in order to enable the mouth to reach the ground. An example of these changes is the modern horse, in which we find the neck and head much elongated when compared with the little *Hyracotherium* and this elongation has taken place *pari passu* with the elongation of the legs. The reduction and disappearance of the side toes and the concentration of the step on the single central toe serve likewise to increase the speed over smooth ground. The soft yielding surface of the polydactyl (several-toed) foot is able to accommodate itself to a rough irregular surface, but on smooth ground the yielding step entails a certain loss of speed. A somewhat similar case is seen in the pneumatic tire of a bicycle; a "soft" tire accommodates itself to a rough road and makes easier riding, but a "hard" tire is faster, especially on a smooth road. Similarly, the hard, firm step from the single toe allows of more speed over a smooth surface, although it compels the animal to pick its way slowly and with care on rough, irregular ground.

The change in the character of the teeth from brachyodont or short-crowned to hypsodont or long-crowned, enables the animal to subsist on the hard, comparatively innutritious grasses of the dry plains, which require much more thorough mastication before they can be of any use as food than do the softer green foods of the swamps and forests.

All these changes in the evolution of the horse are adaptations to a life in a region of level, smooth and open grassy plains such as are now its natural habitat. At first the race was better fitted for a forest life, but it has become more and more completely adapted to live and compete with its enemies or rivals under the conditions which prevail in the high dry plains of the interior of the great continents. The great increase in size, which has occurred in almost all races of animals whose evolution we can trace, is dependent on abundance of food. A large animal, as may be shown on ordinary principles of mechanics, requires more food in proportion to its size than does a small one, in order to keep up a proper amount of activity. On the other hand a large animal is better able than a small one to defend itself against its enemies and rivals. Consequently as long as food is abundant, the larger animals have the advantage over their smaller brethren, and by the laws of natural selection the race tends to become continually larger until a limit is reached, when sufficient food becomes difficult to obtain, the animal being compelled to devote nearly all its time to getting enough to eat.

After Osborn

FIG. 21. EVOLUTION OF THE HIND FOOT OF THE HORSE

Side views of six stages, *Eohippus*, *Mesohippus*, *Miohippus*, *Merychippus*, *Hipparion*, *Equus*

CAUSE OF THE EVOLUTION

THE evolution of the horse, adapting it to live on the dry plains, probably went hand in hand with the evolution of the plains themselves. At the commencement of the Age of Mammals the western part of the North American continent was by no means as high above sea level as it now is. Great parts of it had but recently emerged, and the Gulf of Mexico still stretched far up the valley of the Mississippi. The climate at that time was probably very moist, warm and tropical, as is shown by the tropical forest trees, found fossil even as far as Greenland. Such a climate, with the low elevation of the land, would favor the growth of dense forests all over the country, and to such conditions of life the animals of the beginning of the mammalian period must have been adapted. During the Tertiary the continent was steadily rising above the ocean level, and at the same time other influences were at work to make the climate continually colder and drier. The coming on of a cold, dry climate restricted and thinned the forests and caused the appearance and extension of open, grassy plains. The ancient forest inhabitants were forced either to retreat and disappear with the forests, or to adapt themselves to the new conditions of life. The ancestors of the horse, following the latter course, changed with the changing conditions, and the race became finally as we see it to-day, one of the most highly specialized of animals in its adaptation to its peculiar environment. At the end of the Age of Mammals the continents stood at a higher elevation than at present, and there was a broad land connection between Asia and North America, as well as those now existing. At this time the horse became cosmopolitan, and inhabited the plains of all the great continents, excepting Australia.

It is a question whether the direct ancestry of the modern horse is to be searched for in western America or in the little known interior plains of eastern Asia. It is also unknown why the various species which inhabited North and South America and Europe during the early part of the Age of Man should have become extinct, while those of Asia (horse and wild ass) and of Africa (wild ass and zebra) still survive. Man, since his appearance, has played an important part in the extermination of the larger animals; but there is nothing to show how far he is responsible for the disappearance of the native American species of horse.

PARALLEL EVOLUTION IN OTHER RACES

IT is interesting to observe that while the evolution of the horse was progressing during the Tertiary period in North America another group of hoofed animals, the Litopterna, now extinct, in South America evolved a race adapted to the broad plains of Argentina and Patagonia and singularly like the horse in many ways. These animals likewise lost the lateral toes one after another, and concentrated the step on the central toe; they also changed the form of the joint-surfaces from ball-and-socket to pulley-wheel joints; they also lengthened the

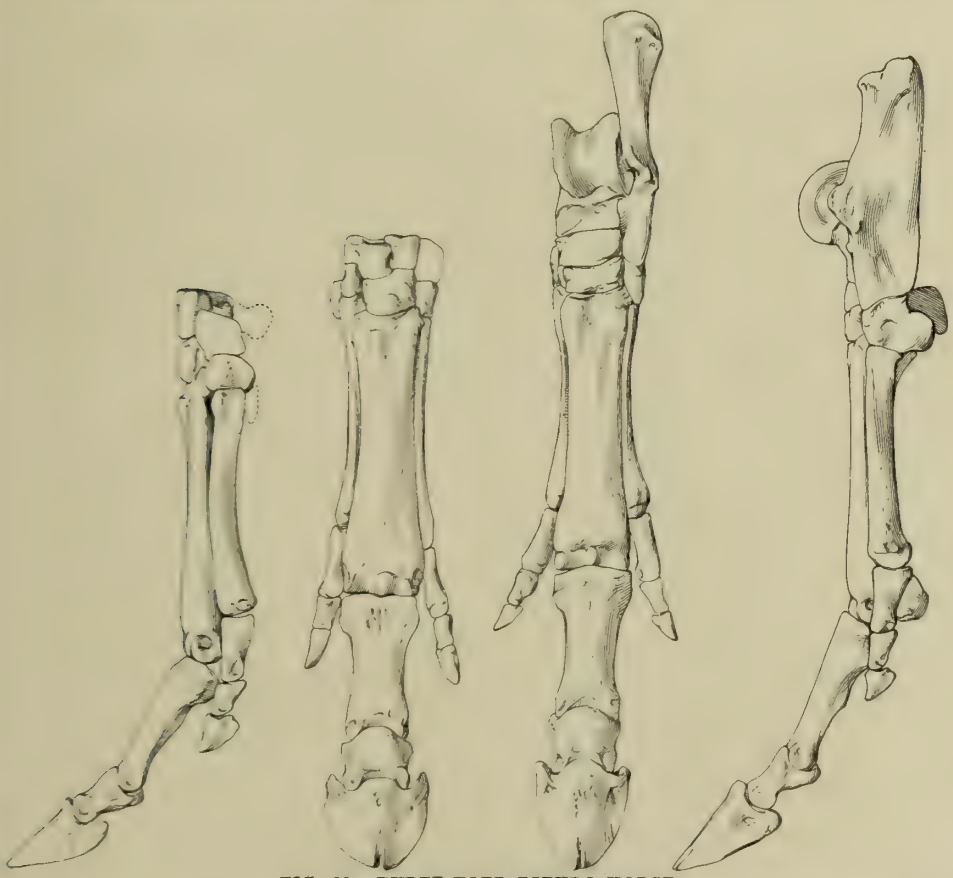


FIG. 22. THREE-TOED PSEUDO-HORSE

Fore and hind feet, one-half natural size. *Diadiaphorus* of the Miocene of South America, although so closely like the three-toed horses in the feet, has a wholly different skull and teeth, and belongs to a different order, the Litopterna, peculiar to South America and now extinct. From specimens in the American Museum

limbs and the neck; and they also lengthened the teeth, and complicated their pattern. Unlike the true horse, they did not form cement on the tooth, so that it was by no means so efficient a grinder. This group of animals native to South America became totally extinct, and were succeeded by the horses, immigrants from North America, which in their turn became extinct from the appearance of civilized man.

Many of the contemporaries of the horse in the northern hemisphere were likewise lengthening the limbs, lightening and strengthening the feet, elongating the tooth-crowns to adapt themselves to the chang-

FIG. 23. ONE-TOED PSEUDO-HORSE

Fore and hind feet, one-half natural size. The *Thoatherium* has gone even further than the modern horse in reducing the side toes to tiny rudiments instead of splints. The skull and teeth show the animal to be closely related to *Diadiaphorus* (Fig. 22) and widely different from true horses. *Thoatherium* was a little larger than a fox terrier and lived in South America during the Miocene Epoch. From specimens in the Princeton Museum and the American Museum of Natural History

ing conditions around them, although none paralleled the horse evolution quite so closely as did the pseudo-horses of South America. But the camels in America, the deer, antelope, sheep and cattle in the Old World, progressed on much the same lines of evolution, although their adaptation was not to just the same conditions of life.

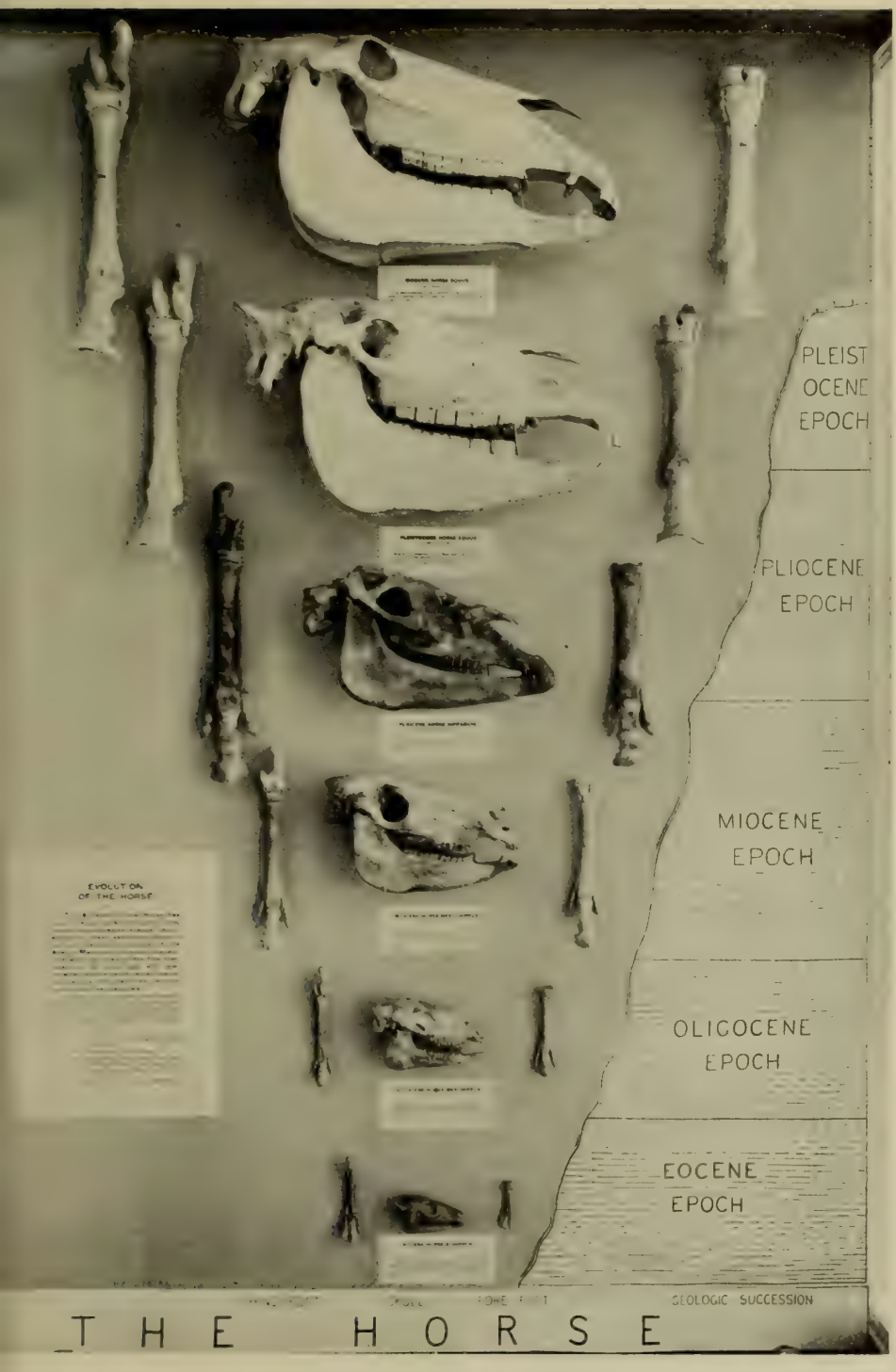
PRINCIPAL STAGES IN THE EVOLUTION OF THE HORSE

Synoptic Panel

In the Horse Alcove is a double panel (pages 36 and 37, somewhat altered in the present arrangement) showing the chief stages in its evolution. On the right-hand panel is the series of skulls, fore feet and hind feet, each stage set opposite the geological epoch during which it lived. Thus all horses found as fossils in the rocks of the Eocene Epoch are Four-toed Horses; all from the Oligocene are small Three-toed Horses with short-crowned teeth, and so on.

On the left-hand panel is a corresponding series of palates to show the gradual change in pattern of the upper teeth, and conversion of the premolars into 'molariform' grinders; and a series of single teeth to show the progressive lengthening of the crown. The change in the brain, the fore leg and hind leg are also shown in this panel, and side views of the fore and hind foot show more clearly the stages in reduction of the side toes.

HIND FOOT
HIND LEG
FORE FOOT
FORE LEG
BRAIN
EVOLUTION OF


PLEISTOCENE EPOCH
PLIOCENE EPOCH
MIOCENE EPOCH
OLIGOCENE EPOCH
EOCENE EPOCH
GEOLOGIC SUCCESSION
THE HORSE

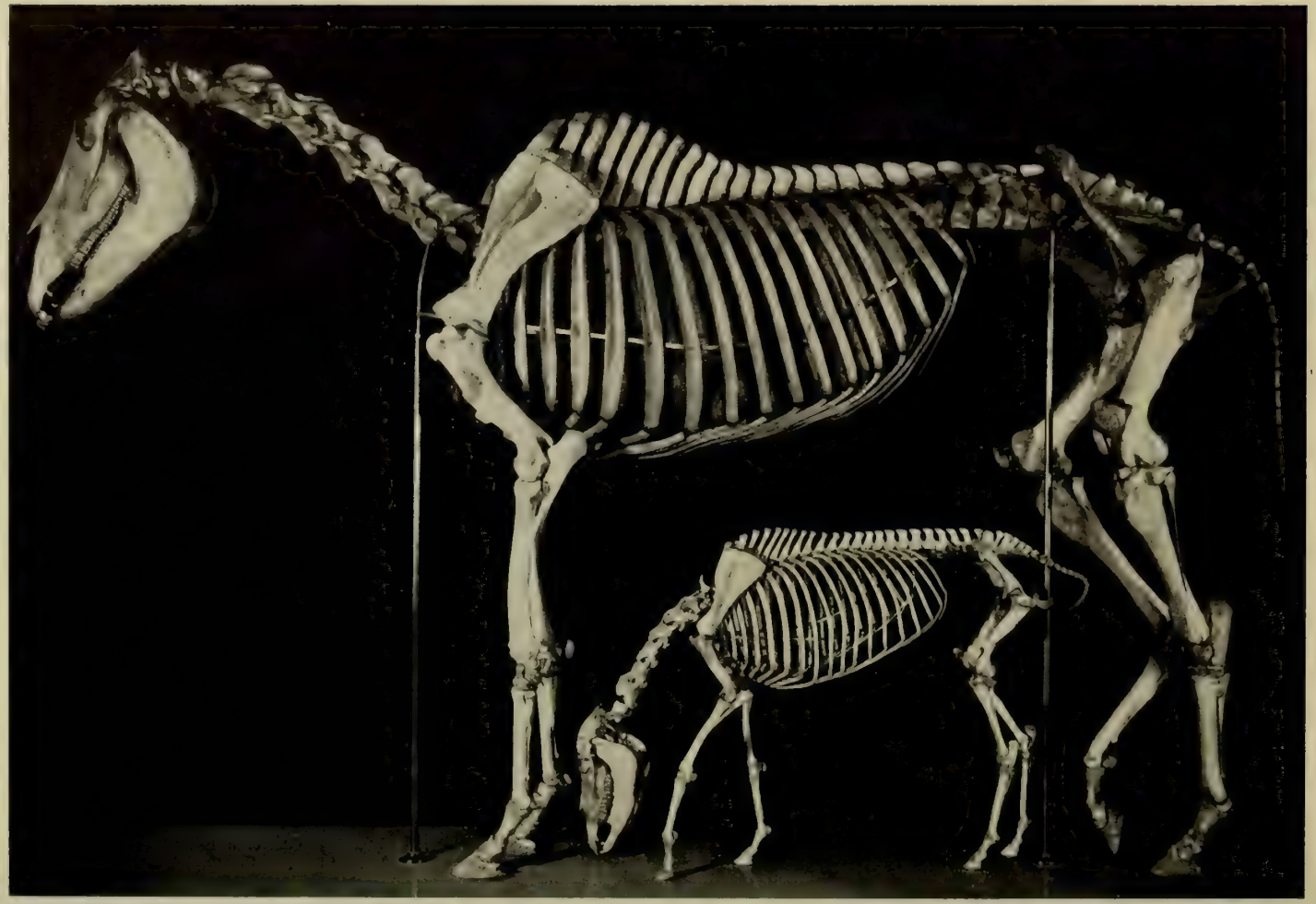


FIG. 25. GIANT DRAFT HORSE AND DIMINUTIVE BUT FULLY ADULT SHETLAND PONY, "HIGHLAND CHIEFTAIN"
Funds for these preparations, a gift of William C. Whitney

Part II. THE HORSE UNDER DOMESTICATION

ITS ORIGIN AND THE STRUCTURE AND GROWTH OF THE TEETH

By S. Harmsted Chubb
Associate Curator of Comparative Anatomy
Skeletons Mounted by the Author

WHEN animals are living under perfectly natural conditions, their physical structure is slowly modified by climate, topography of habitats, and food supply as well as by many other forces. In the struggle for self-preservation among the competitors by which they are surrounded, they develop weapons of defence, or acquire speed mechanism or other means of escape. Thus what we may call natural, as opposed to artificial evolution, is controlled by a great variety of forces, while in a condition of domestication we have development directed in certain lines by man's intelligence.

ORIGIN OF THE DOMESTIC HORSE

IN the light of researches made by Professors Ridgeway, Osborn, and Ewart, there seems to be little doubt that the domestic horse has been derived from several wild types which have since become extinct as wild species. Of two at least we may be reasonably sure: one of Europe or northwestern Asia, which has been called the Norseman's horse; the other from northern Africa, which Professor Ridgeway has called *Equus libycus.*

There is abundant evidence to prove that in the late Quaternary, during and after the Glacial Period, but nevertheless many thousands of years ago, prehistoric man chased and killed wild horses, using their flesh for food and possibly their skins for raiment. This period was followed by a second, during which wild horses were captured, broken to rude harness and driven. The rearing action of the horse skeleton in the group on exhibition in the Museum (Frontispiece) is designed to express unwilling subjection, and the position of the man, as if holding a bridle, intellectual control. The period of early domestication passed insensibly into a third, that of artificial development, during which the horse was modified, and is still being changed in various minor details.

Under man's protection and management, changes are brought about in domestic animals with considerable control and much more rapidly than under perfectly natural conditions. Through training and careful selection in breeding, speed has been greatly increased in the race horse, weight and strength have been developed in the draft horse, while the Shetland pony has been reduced to a most diminutive size.

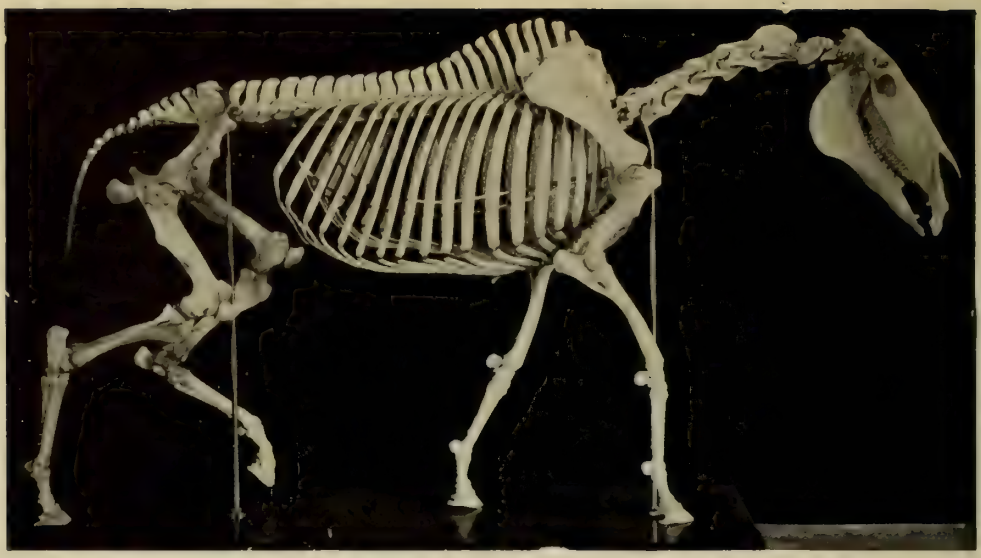


FIG. 26. THE DRAFT HORSE PULLING A HEAVY LOAD
Funds for the preparation, a gift of William C. Whitney. The subject from which the skeleton was prepared was presented by Mr. George Ehret

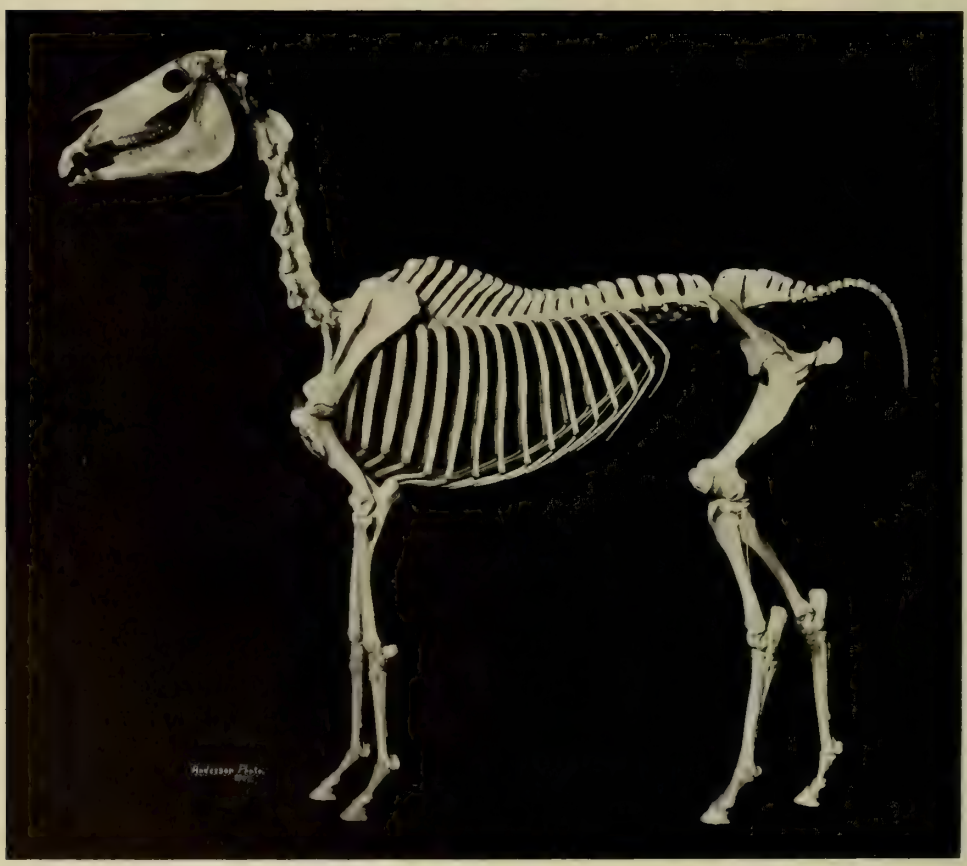


FIG. 27. ARABIAN STALLION, "NIMR"
Mounted in the position of watching a herd. Subject presented by Mr. Randolph Huntington

The intimate relations which have thus existed between the horse and man have influenced both, and it is generally acknowledged by students of mankind that the subjugation of the horse and his adoption, both as a means of transportation and as an aid in agriculture, have been factors of the greatest importance in the later development of the human race.

COMPARISON OF THE SKELETONS OF THE HORSE AND OF MAN

WHILE considering these two skeletons (Frontispiece), it will be worth while to look for a moment into their structure. They are so placed as to facilitate comparison. The one representing a typical or average type of horse, the other a man of about six feet in height and proportionately heavy. The limbs of the horse, moving only forward and backward, have much less freedom of motion than have those of man. Note the ball-and-socket joint of man at the shoulder and hip, the rotary motion of the forearm and the flexibility at the wrist and ankle, and compare with the restricted movement at the shoulder of the horse, the hingelike joint at the elbow, and the limited movement at the wrist (knee) and ankle (hock). The most pronounced differences, however, are found in the head and feet. Compare the skull of man, which has an enormously developed brain and reduced facial portion, with that of the horse which has a comparatively small brain, the face, mouth, and teeth monopolizing almost the whole skull. The feet, instead of having five toes as in man, are reduced to a single digit[1] and they are very much elongated as a speed specialization. And yet a careful study will reveal a most striking similarity between the two subjects in general structure, the differences being simply modifications of a common plan.

THE DRAFT HORSE

THE Norseman's horse of Europe seems to have been an animal with large head, convex forehead and rough coat, of rather clumsy appearance, and of comparatively little speed. It may have been a near relative of the Przewalsky horse which still lives as a wild species in northwestern Mongolia, the only true wild horse known at the present time, the so-called wild horses of the New World being the descendants of domestic horses brought over by the Spaniards during the early settlement of America. Among other evidences of this prehistoric Norse horse, are the many sketches found in the south of France and elsewhere, made by the very primitive cave-dwellers, which seem clearly to depict this type of horse, and it is no doubt this strain which pre-

[1]See page 22.

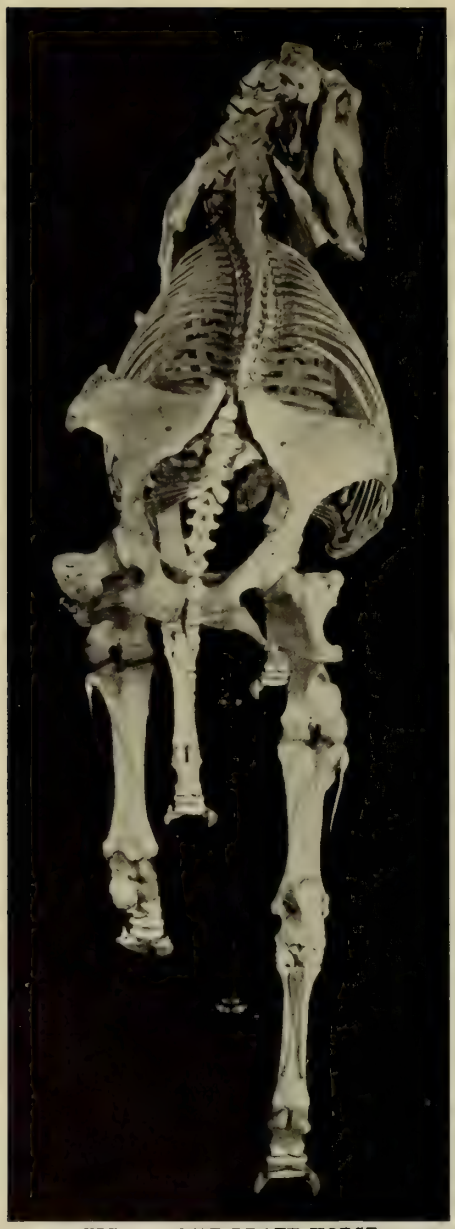


FIG. 28. THE DRAFT HORSE
Rear view showing action of pelvis and backbone

dominates in our heavy draft horse of to-day although of course this horse has been greatly increased in size and strength by long and careful breeding.

An attempt has been made to express the strength acquired in this breed in the mounted skeleton of the draft horse (Fig. 26). This skeleton has been so mounted as to show the action of the bones when the animal is drawing a heavy load. We must imagine that the shoulders rest against a collar upon which the horse is exerting its energy. Note that the head and body are lowered, the hind legs are doing the greater amount of work, the fore legs acting as supports, though a portion of the weight of the body has been thrown against the collar. From the rear view (Fig. 28) note that the right hip joint is much nearer the median line than is the left. The joint is also lower,and indeed,the entire right side of the pelvis has been lowered and thrown well to the left, so that when at the moment of greatest strain the right leg is extended, the pressure upon the anterior part of the body, and thence upon the collar, is applied in a line which more nearly coincides with the main axis of the body. At the next moment the left leg is supposed to be exerted, the right is released, the pelvis then swings to the right, the curve in the backbone becomes reversed, and the pressure is again applied (this time from the left) along the main axis of the body as before; and so on from step to step.

DEVELOPMENT OF GREAT SIZE IN THE DRAFT HORSE

THE skeleton of a very large draft horse is exhibited to show the extreme development of size in this breed. It has been photographed with the skeleton of a Shetland pony to show two extremes in domestic horses (Fig. 25). The following is a table of measurements of the two specimens.

	Giant Draft Horse	Shetland Pony
Height at shoulders	6 ft. 1 in. (18¼ hands)	2 ft. 9⅜ in. (8⅓ hands)
Weight in life	2370 lbs.	170 lbs.
Bulk of humerus	118¾ cu.in.	9½ cu. in.
Bulk of femur	188 cu.in.	13½ cu. in.

The pose chosen for the mounting of this specimen is one of inaction designed to express quiet restfulness, in contrast to the running action of the race horse, to be mentioned later. It shows also a habit peculiar to horses, that of alternately resting the hind legs. Almost the entire weight of the hind quarters is supported on the extended left leg, while the right hind leg rests in a more flexed position and hangs perfectly lax. The pelvis also seems to hang, as it were, from the left hip joint, tilting very much to the right and slightly twisting the vertebral column.

A peculiar function of the patella (kneecap) in the horse is shown in the left knee joint or stifle. While the limb is extended and supports the animal's weight, the patella rests on a projecting articulation of the femur, so that the knee is locked in an extended position by a very strong ligament which holds the patella at a fixed distance from the tibia below, thus sustaining the weight required of it with comparatively little muscular exertion.

An abnormal peculiarity of this specimen is a pair of supernumerary molar teeth, which appear at the posterior end of the upper set. Having no opposing teeth in the lower jaw upon which to wear, they have protruded down into the gum and must have caused the animal considerable discomfort.

THE SHETLAND PONY

IT is highly probable that the Shetland pony is derived from practically the same wild stock as the very much larger draft horse, but has been reduced in size by adverse conditions to which it was subjected in the cold and barren Shetland Islands with their limited area, and also by having been systematically bred for the smallest possible size.

Figure 25 shows the skeleton of an exceptionally small pony which was secured through the Whitney fund. This pony was bred in Scotland and obtained through the kindness of Professor J. C. Ewart of the Uni-

versity of Edinburgh. The skeleton represents the grazing action. It will be seen that the downward reach of the head and the slow, lax step modify the position of almost every bone in the body.

The vertebral column is considerably arched in the dorsal region, as a result of the downward curve of the neck. This arching of the back at the same time tilts the angle of the pelvis a few degrees toward the perpendicular, which slightly raises the hind quarters and tilts the body toward the head, thus enabling the teeth to reach the grass with greater ease. The head being turned well to the right, there is a very slight curve toward the left in the anterior portion of the dorsal vertebræ, and a slight curve to the right in the lumbar vertebræ owing to the backward position of the right hind foot.

The weight of the body falls on the right front and left hind feet, bringing them both very near the median line, and also modifying the position of the scapula and elevating the left side of the pelvis. A little below the left knee a very small hairlike bone may be seen, which represents the shaft of the almost extinct fibula, a bone which was well developed in the ancestors of the horse.

THE ARABIAN HORSE

OF all the many types of horses probably the one most universally admired and loved is the Arabian, with its marvelous grace and beauty, great intelligence, perfection of anatomical mechanism, fleetness, and endurance. The question may well be asked, whence comes this superiority?

The great fondness and care with which the Arabs have bred their horses for many hundreds of years have undoubtedly done much for the elevation of the stock; but more than this it is shown almost conclusively that the Arab was blessed with a wonderfully fine natural species on which to exercise his care. On this point Professor William Ridgeway, of Cambridge University, has given us an immense mass of most convincing evidence.[1]

There are many reasons, traditional and historical, as well as zoological, for believing that the Arabian horse, or as Professor Ridgeway has called it, the Libyan horse, is in origin entirely separate from the very much inferior northern or Norseman's horse, and that its native home was not in Arabia but northern Africa, where it was domesticated by the ancient Libyans, in all probability as early as 2000 B.C.

[1]RIDGEWAY, WILLIAM. Origin and Influence of the Thoroughbred Horse. Cambridge: Univ. Press, 1905.

The Egyptians also knew full well the value of domestic horses. "Egypt was, in fact, famous for its breed of horses which were not less excellent than numerous, and we find that they were even exported to other countries, Judea, Syria, and to the Kings of the Hittites."[1] It is also clear, from Egyptian art, that these horses were of the North African, or as we would say to-day, Arabian type. It has been the constant infusion of this Libyan blood which has tended to improve our commoner horses for these many centuries.

The skeleton of Nimr (Fig. 27), a pure-blooded Arabian stallion, has been mounted to show some of the conspicuous characteristics of this species, which are as follows:

1. Head and tail carried high when the animal is animated;
2. Skull short, but broad between the eye sockets;
3. Eye sockets high and prominent, giving the eyes a wide range of vision;
4. Facial profile, or forehead, concave;
5. Muzzle slender, but jaw deep and wide above the throat;
6. Round thorax, well "ribbed up" and short back with only five ribless, or lumbar vertebræ;
7. Horizontally placed pelvis (a speed character) and very high tail region, few tail vertebræ;
8. Long and slender cannon bones and long sloping pasterns.[2]

Nimr was sired by the desert-bred Arabian, Kismet, famous for an unbroken series of victories as a race horse in India. After his death at Oyster Bay, Long Island, in 1904, the remains were presented to the Museum by the owner, Mr. Randolph Huntington.

THE RACE HORSE

AS for the earliest domestication of the horse in Britain, where the race horse or thoroughbred has since been developed, no definite statement can be made. We read that horsemen in large numbers opposed the landing of the Romans, and also that in 631 A.D. the English first began to saddle their horses. Again we find mention of "running" horses in the ninth century. But it was not until about 1689, when the famous Byerley Turk was brought to England, that we learn anything definite concerning the origin of the present English stock, though horses of undoubted North African blood had been imported from Turkey a century or more earlier.

The Darley Arabian, bred in the desert of Palmyra, was imported into England by Mr. Darley in 1705. About twenty years later the

[1] WILKINSON, I. G. Ancient Egyptians.

[2] OSBORN, H. F. Points of the Skeleton of the Arab Horse. Bull. Amer. Mus. Nat. Hist., vol. xxiii, art. 13, pp. 259–263, 1907.

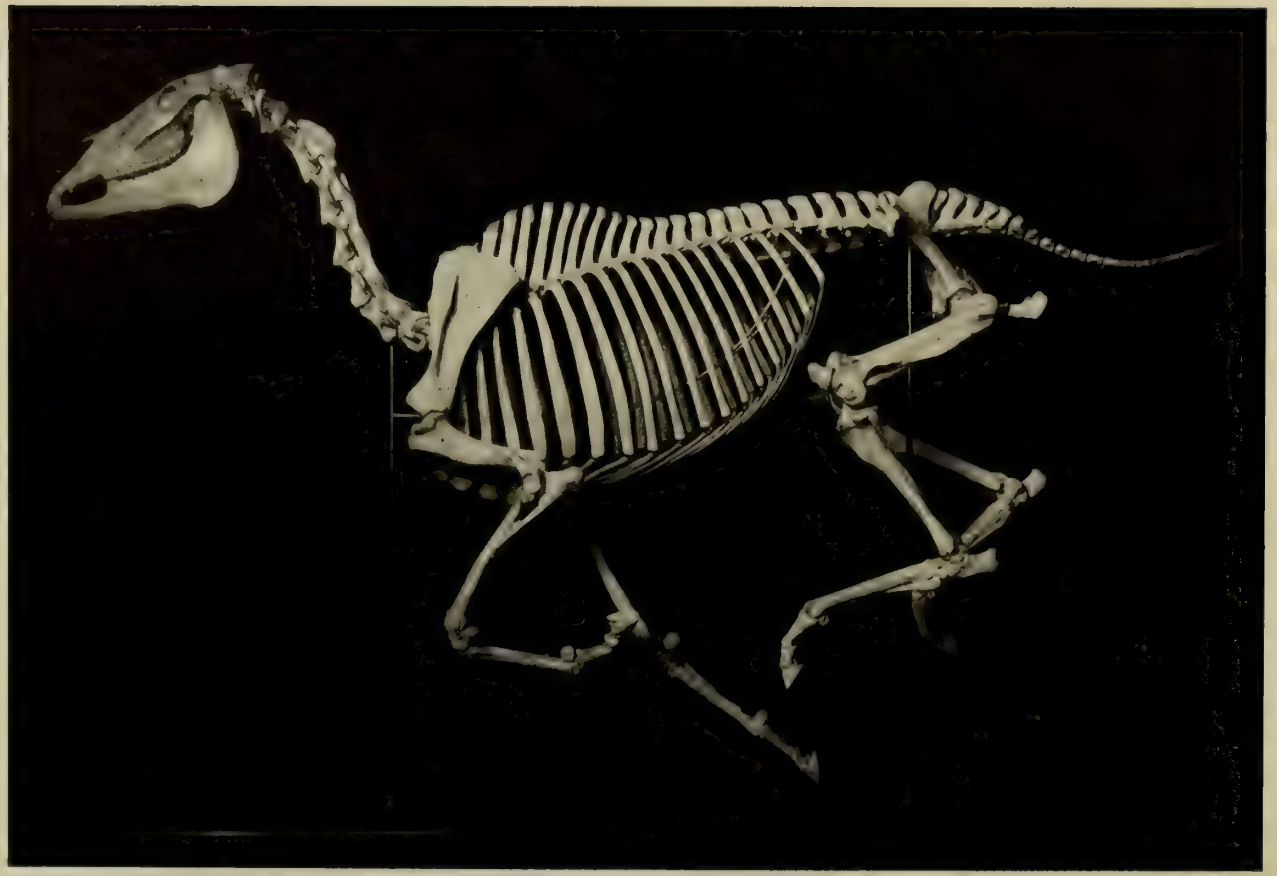


FIG. 29. THE FAMOUS AMERICAN RACE HORSE, "SYSONBY." SHOWING ACTION IN THE FAST RUN
Subject and funds for the preparation, a gift of James R. Keene

Godolphin Arabian[1] arrived on the scene, continuing to improve the English stock with infusion of North African or Libyan blood, to which the quality of the race horse is chiefly due.

Touchstone states, "The thoroughbred, as soon as he ceases to be subjected to the special régime of training, reverts to the Arab type with such extraordinary rapidity that we cannot be blind to the fact that he descends, for at least seven parts out of eight, from the pure Arab,"[2] which we would consider of Libyan origin; and indeed many admirers of the Arab would gladly eliminate the remaining eighth of non-Arabian blood.

However, the race horse of to-day is a very highly specialized animal, certainly vastly different in appearance from the Arab and yet still more widely separated from the draft-horse type.

In July, 1906, we were particularly fortunate in the gift from Mr. James R. Keene of the remains of one of America's most famous race horses, together with sufficient funds for the preparation of the skeleton.

This remarkable horse, Sysonby, was foaled February 7, 1902, at Mr. Keene's Castleton stud in Kentucky, a few months after the importation from England of his dam, Optime, his sire being the English bred Melton. His record, at the time of his death, was one of the most brilliant in the history of American horse-racing. He won a remarkable series of victories between his first race at Brighton Beach, July 14, 1904, as a two-year-old, and his untimely death at four years, July 17, 1906.

The skeleton (Fig. 29) has been mounted to show a phase in the stride of the running horse, and is based on studies made from direct observation and instantaneous photographs. The position is that of the moment after the right fore foot has left the ground, and the right "knee," or carpus, is beginning to bend; the succeeding footfalls in order are the left hind, the right hind, the left fore, and the right fore, the full length of one complete stride being about twenty-five feet.

At this instant the hind quarters are lifted perceptibly higher than the shoulders and from a rear view it will be seen that while the hind feet are thrust forward at this greater height from the ground, they are widely separated so as to avoid striking the fore legs. A moment later the shoulders will be lifted by the push of the fore feet higher than the hind quarters, then the hind feet will move toward the median line and strike the ground, and the fore feet will have moved forward out of the way of the hind. While in Fig. 29 the two left feet are moving in advance of the right, this order is often reversed, resulting in a right lead.

[1]Richard Berenger, however, denies that this horse was an Arab, though his view is not generally accepted. *History and Art of Horsemanship*, 1771.

[2]Touchstone, S. F. Race Horses and Thoroughbred Stallions.

The backbone is slightly arched to help draw together the fore and hind feet. Then the back muscles are brought into action straightening the spine and thus lengthening the stride. When viewed from above, or from the rear, the backbone is also observed to be curved a little to the right, owing to the forward position of the left side of the pelvis and of the left hind limb. As the left foot moves backward the spine is straightened laterally and then the curve reversed, thus further contributing to the power and length of the stride.

THE RUSSIAN WOLFHOUND COMPARED WITH THE RACE HORSE

THE skeleton of a Russian wolfhound (Fig. 30) has been mounted to show a most extreme action in the progressive movement, and also to make a comparison between the running action of the horse and of the dog. To facilitate this comparison, the moment in the stride which has been selected for the preparation of this specimen is approximately the same as that chosen in the case of the running horse, Sysonby. The two skeletons also furnish an interesting example in comparative osteology.

With the exception of a few peculiar and highly specialized forms, the laws governing animal locomotion among terrestrial mammals are practically the same. Certain principles are strictly adhered to by animals so diversified, for instance, as the horse, the squirrel, or the mouse.

Nearly all mammals have three natural gaits, the walk, the trot, and the run. These respective methods of locomotion vary so slightly in different animals that it will be interesting to point out some of the minor differences. The dog, a much smaller animal yet approximating the horse in speed, must necessarily acquire a much more extreme action than does the horse, but the differences are mostly matters of degree. For instance, at the moment when the limbs are drawn together the spine of the horse is slightly arched. Compare this with the very strongly curved back of the dog. And while the hind toe of the horse comes in line with the pastern of the front foot, the limbs of the dog cross not far from the knee of the hind leg and the elbow of the front. It is also found that when the horse is running at full speed he is entirely free from contact with the ground approximately one-fourth of the time, that being the moment when the limbs are drawn together under the body, while the dog is suspended in air about one-half of the time, being free from the ground twice during each stride, once when the limbs are drawn together and again during the extended position.

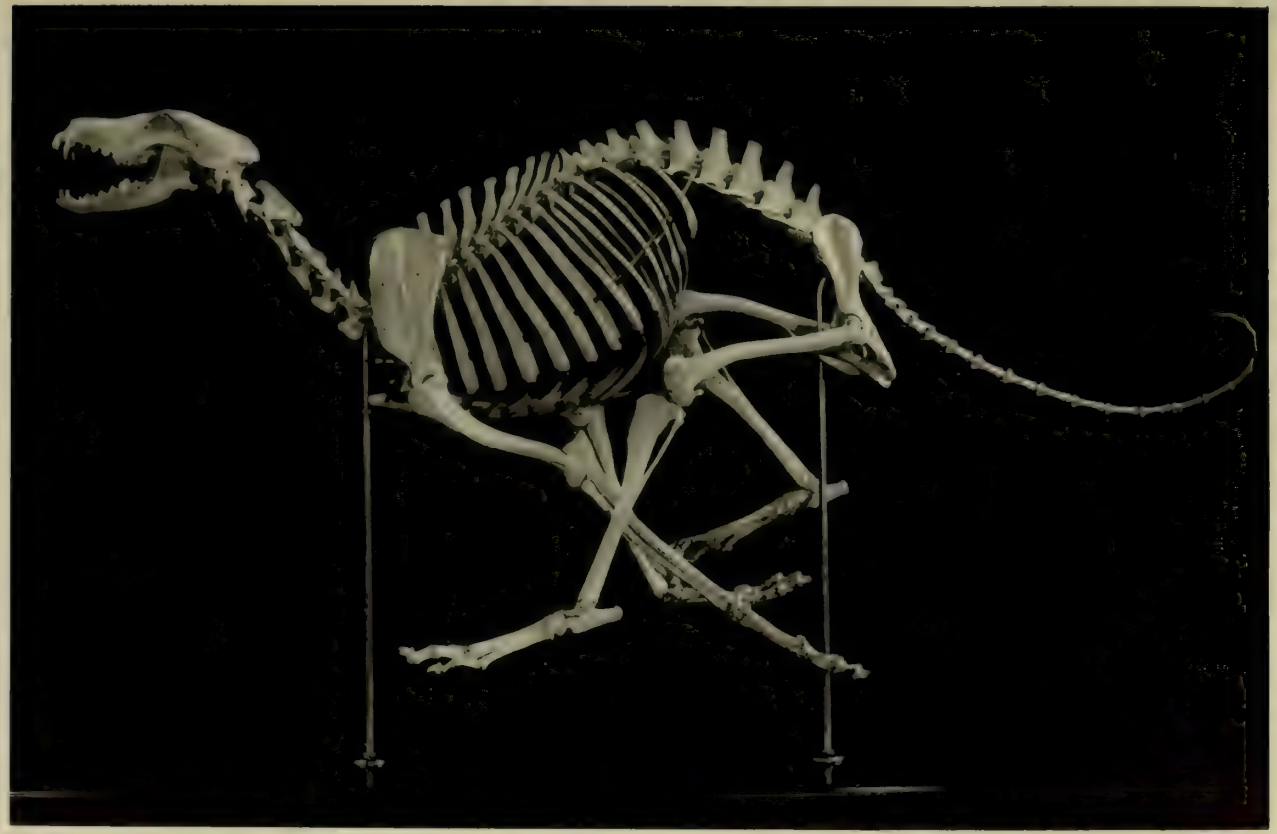


FIG. 30. RUSSIAN WOLFHOUND

Mounted to show the fast running action of the dog as compared with the horse

There is, however, one technical difference between the running action of the horse and that of the dog, that of the succession of footfalls. Let us compare the action represented by these two skeletons. In each case, the next foot to strike the ground will be the left hind foot and then the right hind, but the horse will follow the right hind foot with the left front, and then the right front foot. Hence it may be called the diagonal run.

The dog, on the other hand, prefers the rotatory run, striking the right front foot after the right hind, and so on around, so that at the moment when the limbs are drawn together under the body the two which come more nearly in contact with each other are those of the same side, while with the horse they are of opposite sides.

From a rear view, it will be observed that when the hind feet are moving forward for another spring they are widely separated and pass safely outside of the fore feet, thus avoiding danger of collision. The very same method of safety is followed by the horse and practically all four footed mammals during the run. It may be said, however, that the apes, with their tendency toward a bipedal action, are somewhat irregular in this respect.

THE TROTTING HORSE

THE importation, in 1788, of the English thoroughbred stallion, Messenger, was the first step toward the development of the fast American trotting horse, but it was not until nearly seventy-five years later that Rysdyk's Hambletonian began to attract a great deal of attention. This sire had inherited, through both parents, much of the blood of the English horse, Messenger, and his many descendants showed a remarkable aptitude for the fast trot, a somewhat unnatural gait acquired only through adaptability, selective breeding, and special training, which has resulted in a distinct breed. The more normal trotting action is a gait of moderate speed intermediate between the walk and the run.

For the further development of the Museum's collection of Equidæ it was most essential that a specimen should be obtained to show this specialized type of horse, and also to show the action of the bones in this acquired trotting gait at high speed. After waiting many years, this opportunity was presented by the untimely death of Lee Axworthy, 1:58¼.

Through the kind interest of Mr. David M. Look, the remains of the champion trotting stallion were presented to the Museum by his owners, Messrs. Frank H. Ellis, H. K. Devereux, Coburn Haskell, and P. W. Harvey of the Pastime Stable.

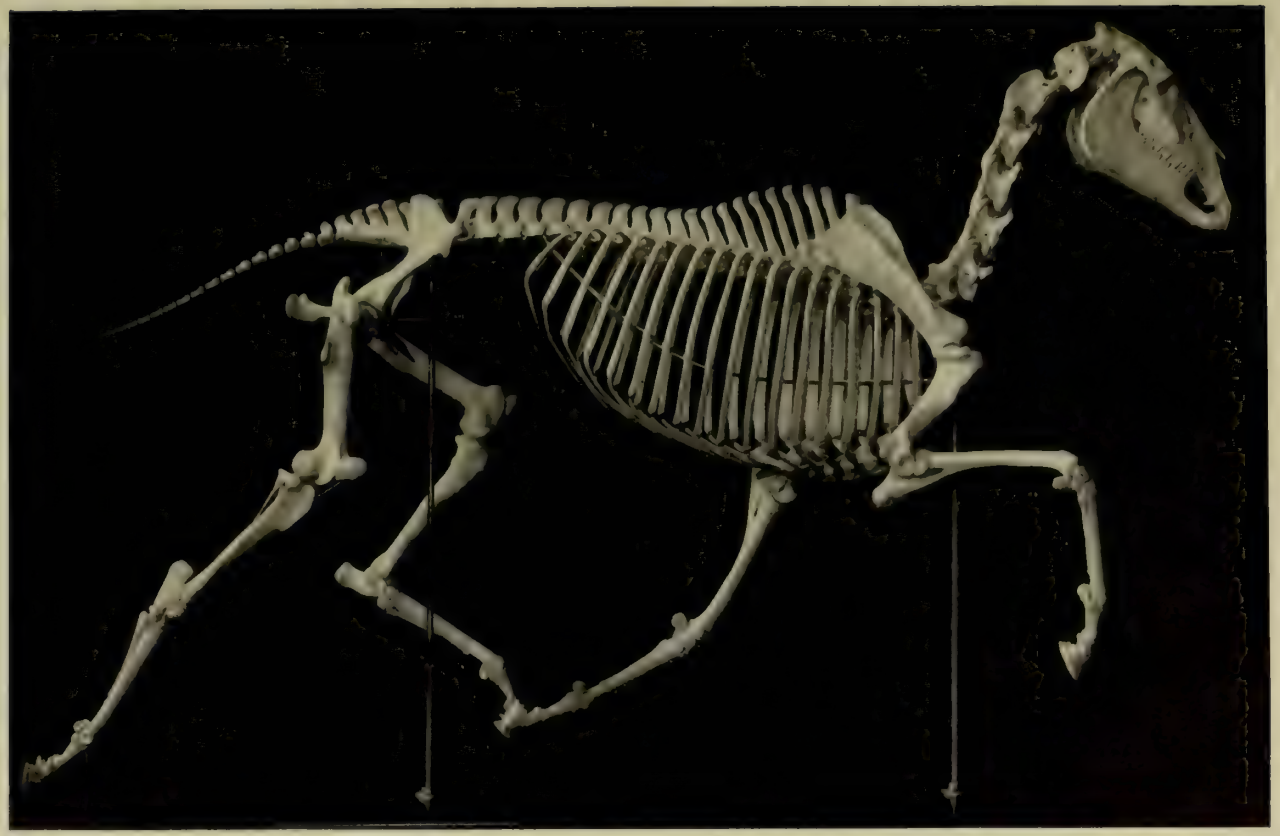


FIG. 31. "LEE AXWORTHY," THE WORLD'S CHAMPION TROTTING STALLION, 1.58¼

Skeleton mounted to show action of bones in the fast trot. Funds for the preparation, a gift of Watson B. Dickerman. Subject presented by the Pastime Stable

The preparation of the skeleton was made possible by the generosity of Mr. Watson B. Dickerman, who also rendered most valuable co-operation in the use of his training track for the necessary study of the trotting action.

Lee Axworthy, the first trotting stallion to make a mile record faster than 2:00 minutes, was foaled at Donerail, Kentucky, in the spring of 1911. He was sired by Guy Axworthy, 2:08¾, and his dam was Gaiety Lee, 2:16¾.

As a three year old he made a record of 2:08, which he reduced in 1916 as follows:

August 22	North Randall, Ohio	2:00¼
September 12	Syracuse, New York	2:00
October 4	Lexington, Kentucky	1:59½
October 8	Lexington, Kentucky	1:58¼

The following spring he was retired to the stud at Castleton Farm, near Lexington, Kentucky, where he died suddenly on November 7, 1918.

The skeleton of Lee Axworthy (Fig. 31) has been prepared to show the extreme action in the fast trot, and is based on studies made in dissection, direct observation of living animals, and from instantaneous photographs taken on the track. The position selected is that which occurs the moment after the right hind foot has left the ground, the left fore foot having been lifted a fraction of a second earlier. The footfalls in order are as follows: the right fore foot, then the left hind foot, giving a perceptible period of contact with the ground. When these two feet are lifted there follows the period of complete suspension, after which the left fore foot and then the right hind foot will strike the ground. With some trotters this order is reversed, the hind foot striking a very minute fraction of a second earlier than the opposite fore foot. An individualism of the present subject is the high action of the fore feet.

From a rear view it will be seen that the left hind foot is moving forward with an outward curve, thus safely clearing the fore foot. Instantly the fore foot will move forward out of the way of the hind foot, which will then curve in toward the median line and strike the ground.

At the present moment the backbone is slightly curved to the right, owing to the drawing together of the left feet and the wide separation of the right feet.

WILD SPECIES OF THE FAMILY EQUIDÆ

AMONG the Equidæ still represented as wild types are a number of species of asses and zebras, none of which are so closely related to our domestic horses as the Przewalsky, the wild horse of Mongolia, already referred to on page 41.

On exhibition is a skeleton of the Kiang, *Equus kiang*. This species still roams freely over the plateaux of Tibet and Central Asia. Although the external appearance is ass-like, there are certain characteristics of dentition and skull formation which would relate it much more closely to the horse than is our domestic donkey, *Equus asinus*.

The Kiang skeleton shows the action in the slow trot which differs greatly from the acquired action of the trained trotting horse. Although great as these differences are, they are merely results of degree in speed.

There is also mounted a skeleton of the Grant Zebra, *Equus granti*, a native of British East Africa, and one of the Chapman Zebra, *Equus chapmani*, of Central South Africa.

The positions selected for the preparation of these two specimens show phases in the walking action. In these slow movements the animal is never in complete suspension, but is in contact with the ground on at least two feet, and during part of the stride, on three feet at the same time.

THE TEETH OF THE HORSE

[COLLECTION IN WALL CASE]

THE dental apparatus of the horse is one of the most interesting and highly specialized organs that we find in nature. During the course of evolution through many ages, the teeth have gradually grown more and more complex, becoming constantly more perfectly adapted to the cropping and grinding of coarse, hard grasses. They are, in fact, of such great size and importance that the whole skull seems constructed chiefly for their lodgment and operation, the custody of the brain, eyes, and ears being, as it were, of secondary consideration; hence the skull must of necessity be very bulky and, in order that the weight may not be unnecessarily great, large air spaces (sinuses) are provided, aggregating between two and three times the amount of space occupied by the brain (specimens 51 and 5, on exhibition in wall case). Indeed the skull of the horse is a beautiful design in arches and braces, resulting in a structure of the greatest possible strength and utility with a minimum of weight and material.

The ethmoids, the bony framework of the organ of smell, are also highly developed, with a complicated system of scrolls presenting an immense amount of surface to the air that is drawn into the nostrils (specimens 5, 10 and 51).

STRUCTURE OF THE TEETH

A VERY simple form of tooth is that commonly found among the reptiles, a mere peglike structure composed of dentine with a very much harder covering of enamel on the crown, and a nerve canal in the center. We have selected three incisor teeth of less simple form (Fig. 32) to show examples of different degrees of specialization. *A*, the tooth of a young cow, is of comparatively simple form, being somewhat flattened and having a clearly defined line or neck between the crown and the root. The crown is composed of dentine completely covered with enamel, on the surface of which is deposited a thin and incomplete layer of a third element known as cement. The root is of dentine with a pulp or nerve cavity running through it and extending into the crown. The neck, or base of the crown, as in most simple teeth, coincides with the line of the gum. In the horse the composition of the teeth is the same except that the cement, which begins to be deposited on the surface some time before the eruption of the young tooth, covers the enamel more completely and is very much thicker. In design it is more complicated. Instead of the plain upper border, as in Fig. 32*A*, there is a very deep indentation or folding in of the enamel, somewhat like the inverted finger of a glove, forming an enamel lined cup or cul-de-sac, running far down into the tooth (Figs. 32*C* and *D*), becoming more or less completely filled, particularly toward the bottom, with a deposit of cement. It is usually observed that highly specialized organs are more primitive in the young individual than in the adult. This is very noticeable in Fig. 32*B*, which represents the deciduous or milk incisor of a colt about four days old. This tooth has just cut through the gum, and does not as yet show any wear from use. The enamel cup is very shallow as compared with that of the permanent tooth (*C* and *D*). It also shows a clearly defined line at the base of the crown which, when the tooth is fully grown, will coincide with the line of the gum as in the teeth of the cow and other simple teeth. The root, not being fully grown, does not taper to a point as it will later, but presents a wide opening at the base, which will be gradually reduced to a small foramen for the passage of the nerve (Fig. 33*h*). At the early stage shown in Fig. 32*B*, the pulp cavity is very large, so that the young tooth is a hollow shell. Figure 32*C* shows the permanent incisor of a colt two years old, which will erupt and replace its deciduous predecessor at about three and a half years. The cul-de-sac is very deep, running down more than half the length of the crown. The root has not yet begun to develop. There is already considerable cement in the cul-de-sac, and a very slight deposit beginning on the external surface about the upper end of the crown. The pulp cavity is, proportionately, much smaller than in *B*. A series of vertical sections of incisor teeth, exhibited in the wall case, will explain the structure more clearly.

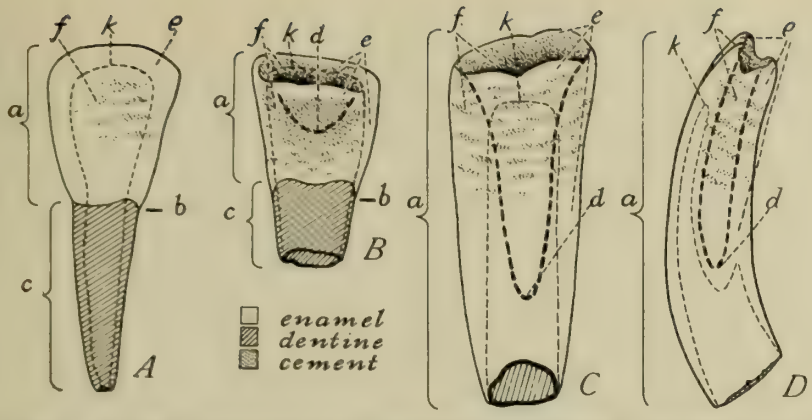


FIG. 32. INCISOR TEETH SHOWING DIFFERENT DEGREES OF SPECIALIZATION

Natural size

A. Permanent tooth of young cow. *a*, crown; *b*, base of crown; *c*, root; *e*, enamel; *f*, cement deposited on enamel; *k*, apex of pulp or nerve cavity
B. Deciduous tooth of colt 4 days old. *a*, crown; *b*, base of crown; *c*, incomplete root; *d*, bottom of cul-de-sac; *e*, enamel; *f*, cement; *k*, apex of pulp or nerve cavity
C. Permanent tooth of colt 2 years old. *a*, crown; *d*, bottom of cul-de-sac; *e*, enamel; *f*, cement; *k*, apex of pulp or nerve cavity
D. Side view of C. (A, B, and C, posterior views)

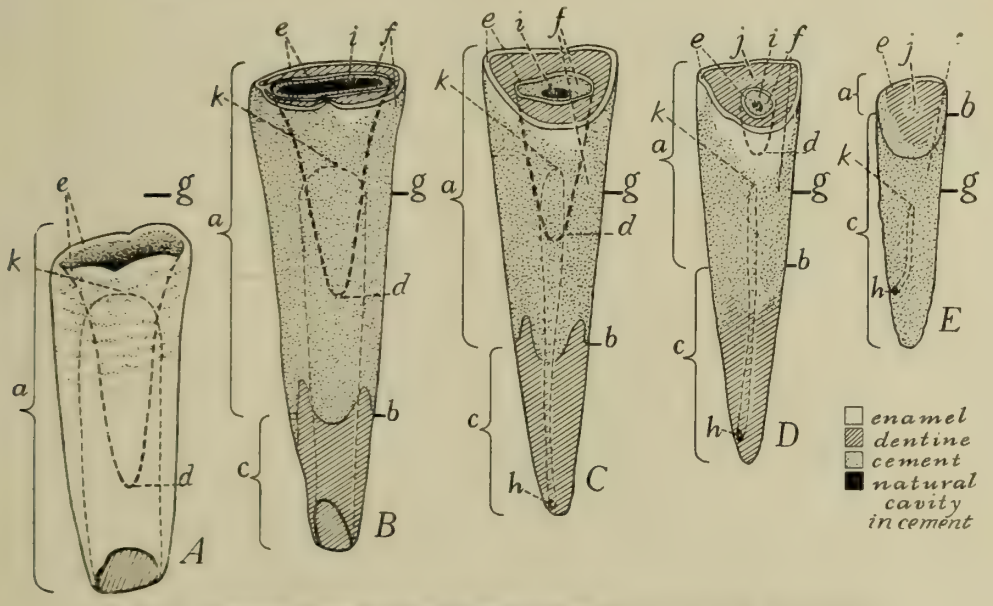


FIG. 33. INCISOR TEETH OF THE PERMANENT SET SHOWING WEAR AND MOVEMENT

Posterior view. Natural size.

A. Unerupted tooth of a colt 2 years old. *a*, crown; *d*, bottom of cul-de-sac; *e*, folded edge o enamel, unworn; *g*, gum line; *k*, apex of pulp or nerve cavity
B. Tooth of horse 4 years old. *b*, base of crown; *c*, incompleted root; *e*, worn edges of enamel; *f*, internal and external cement; *i*, natural cavity in cement
C. Tooth of horse 12 years old. *c*, root fully grown; *h*, nerve foramen
D. Tooth of horse 17 years old. *j*, "dental star"
E. Tooth of horse 33 years old. *f*, cement, external only

WEAR AND COMPENSATING MOVEMENT OF THE INCISORS

WHAT is frequently spoken of as "growth" in the horse's teeth is not growth, but rather movement. It is true that growth does continue in some few of the teeth until the horse is ten or twelve years old, but only in the completion and closing of the roots, as noted above, the crowns being all fully developed, including grinders as well as incisors, at about five and one-half years. Long before the tooth has commenced its service, it begins to move from the alveolar cavity, or dental grouve, which fills with new bone at the base. This movement counteracts the rather rapid wear of the cutting or grinding surface, so that in extreme old age some of the teeth may be worn down to the very points of the roots. One of their most remarkable specializations is the extremely long crown which instead of being entirely above the gum line, as with the more simple teeth, human for instance, extends far down into the alveolar cavity, 3⅝ inches in the large premolars, as a reserve of grinding material. Figure 33 shows a series of incisors to explain the manner in which the tooth is worn as it proceeds from the alveolar cavity, the wearing surface altering in contour as it progresses along the crown of the tooth which constantly changes in shape toward the root.

A is the permanent tooth of a colt two years old, before it has replaced its deciduous predecessor or has received any wear, so that the external enamel is continuous with that of the cul-de-sac or internal enamel. The cement now lines the cul-de-sac and is beginning to be deposited on the external enamel. As yet the tooth is without root, but has a wide-open pulp cavity which extends far up into the tooth, passing between the cul-de-sac and the anterior wall of the tooth. This is more clearly shown in the side view (Fig. 32*D*).

Fig. 33*B* is the tooth of a horse about four years old. It has recently replaced its deciduous predecessor, having been in use only about six months. The folded edge of enamel is worn through, exposing the dentine beneath, and separating the enamel of the cul-de-sac from that of the exterior, with the exception of a very slight connection at the left-hand border. Internal as well as external enamel is covered with cement except on the wearing surface. The base of the crown is not clearly defined but can readily be located as it coincides with the lower border of enamel. It will be seen that this point, instead of being at the surface of the gum as in more primitive teeth, is planted about an inch and one-fourth deep, *g* indicating the gum line.

C, the tooth of a horse about twelve years old, shows a roughly triangular wearing surface, having been worn down a distance of perhaps three-eighths or one-half inch. The cul-de-sac is greatly reduced in surface diameter, as well as in depth. The root is fully developed and shows a somewhat shorter and very much narrower nerve cavity, with the nerve foramen (*h*) at the point. With the advance of age the wearing surface of the tooth, molar as well as incisor, must necessarily approach the nerve, which would subject it to exposure. This is provided for by the recession of the nerve and a new growth of dentine, reducing the pulp or nerve cavity and sometimes in extreme old age completely filling it.[1] As the tooth wears down this new dentine can be detected in the incisor by a slightly lighter shade in color, and is known among horsemen as the "dental star." It is indicated in *D* and *E*.

In *D*, showing the tooth of a horse about seventeen years old, the wearing surface is more nearly triangular. The cul-de-sac is almost worn away; the base of the crown is approaching the gum line. Not only is the cement thickly covering the crown, as in the younger teeth, but it is encroaching upon the root as well so that the base line of the crown is obliterated, but can readily be located by sectioning. On the more exposed ridges, however, particularly the anterior surface not shown in the sketch, the cement has been worn through in places by friction of the tongue and lips.

E shows the condition in extreme old age, this specimen being the tooth of a horse thirty-three years old. The cul-de-sac has long since been worn away and the only enamel remaining is a very narrow strip on the anterior border, the base of the crown having passed beyond the gum line. The wearing surface has become elliptical, and the "dental star" has changed from a transverse stripe to a rounded spot. The nerve cavity is reduced to a narrow canal. The deposit of cement has increased, in some places, to almost an eighth of an inch in thickness particularly at the point of the root, which has extended far beyond the nerve foramen (*h*) at the side. This thickening and extension of the root by cement would seem to be a provision to prolong the tooth's service to the very last.

It is by the examination of these indications that horsemen ascertain the age, although it is impossible to judge accurately in the more advanced stages. Especial attention is given to the size and shape, presence or absence of the cul-de-sac, known among horsemen as the "mark." It should be explained, however, that the lower incisors which are more easily examined in the living horse, being somewhat smaller

[1]See specimen No. 132 under "Longitudinal Sections of Grinding and Incisor Teeth," on exhibition in wall case.

and having a shallower cul-de-sac than the uppers just described, will acquire a certain appearance of wear at an earlier age. For instance, if *C* and *D* were lower teeth they would have a similar appearance at the ages of eight and twelve years. Considering the incisor set as a whole, it shows other marked changes with the advance of age. To render effective service the teeth must be in close contact; therefore, as each tooth is reduced in diameter it moves slightly toward the median line, reducing the total transverse measurement of the set. The meeting angle of upper and lower teeth becomes much more acute in old age. An exhibit labeled "Series of Horse Muzzles" in the wall case shows the general appearance of the incisor teeth at various ages.

The canine tooth is of comparatively simple structure and has no apparent function at the present time, but may have been of service as a weapon at a very early stage of evolution. It receives almost no wear, has little or none of the compensating movement of the incisors and is, in fact, of no very great interest. This tooth is very rarely found in the female except in an abortive form.

DESIGNATION OF THE TEETH

THE deciduous or milk teeth, which are shed and replaced by permanent ones, are divided into three classes: in front, the deciduous incisors, back of these, the very small deciduous canines, and still farther back, the deciduous molars.

In the permanent set the incisors and canines have replaced their deciduous predecessors, and the deciduous molars have been replaced by the premolars. Still back of the premolars comes a fourth class, the permanent or true molars, which have no deciduous predecessors.

In works on comparative anatomy and zoology the teeth are expressed by initial letters and numerals in fractional form; the numerator denotes the number of upper teeth, and the denominator the number of lower teeth of each class, running back from the median line in front, and considering only one side of the skull. For instance the typical mammalian milk dentition is as follows, all being deciduous teeth; incisors three, canine one, molars four, which would be expressed *d. i.* $\frac{3}{3}$, *d.c.* $\frac{1}{1}$, *d.m.*$\frac{4}{4}$. The permanent dentition would be *i.* $\frac{3}{3}$, *c.* $\frac{1}{1}$, *p.m.* $\frac{4}{4}$, and *m.* $\frac{3}{3}$—forty-four teeth in all. The human subject having only thirty-two permanent teeth, would be expressed *i.* $\frac{2}{2}$, *c.* $\frac{1}{1}$, *p.m.* $\frac{2}{2}$, and *m.* $\frac{3}{3}$.

The teeth are numbered from the median line, hence when indicating a certain tooth *i.* $\frac{3}{3}$ would be read, lower incisor three; *pm.*. $\frac{4}{}$, upper premolar four: lower deciduous canine is expressed *d.c.*—. Figure 34 shows the designation of deciduous and permanent teeth of the horse. *A* is the

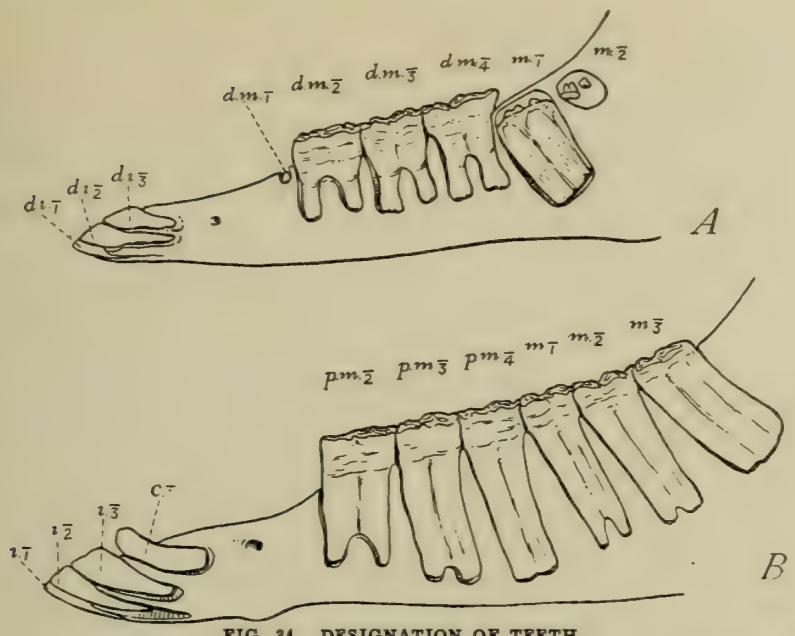


FIG. 34. DESIGNATION OF TEETH

A. Lower jaw of colt 9 months and 12 days old, marked to show designation of deciduous teeth. Specimen No. 36

B. Lower jaw of horse 5 years old, marked to show designation of permanent teeth. Specimen No. 26

lower jaw of a colt nine months and twelve days old, in which the deciduous dentition is all in use, and though the eruption of the molars has not yet begun, the development of one at least is well under way. In *B*, a horse about five years old, the permanent teeth are all in place. It must be borne in mind that when a subject has a reduced dentition the teeth are numbered not necessarily as they appear in the jaw, but according to what is believed to be their true relation in the typical dentition, having forty-four teeth. For instance, in the human subject where there are but two premolars, known among dentists as bicuspids, the first one in the lower jaw would be expressed *pm.* $\overline{3}$. The second would be *p.m.* $\overline{4}$, assuming that *p.m.* $\overline{1}$ and *p.m.* $\overline{2}$ are the missing teeth. The teeth of specimens on exhibition, Nos. 10 and 36, are labeled in the manner described.

THE "WOLF" TOOTH OF THE HORSE

IN the horse we may say that *p.m.* $\frac{1}{1}$ (Fig. 39*B*) is now in the last stage of elimination. Just in front of the upper premolars there is frequently found a very small abortive tooth commonly known as the "wolf" tooth. It does also occur in the lower jaw but is very rare. It is absolutely non-functional, and is in fact detrimental, as it sometimes gives rise to more or less irritation. So that in the horse the first func-

tional premolar is *p. m.* $\frac{3}{2}$. The "wolf" tooth, though interesting, is rather difficult to study owing to its irregularity. When speaking of the permanent teeth it is generally designated as *p.m.* $\frac{1}{-}$, which would be correct if it really belonged to the permanent set; this, however, I am inclined to doubt, although it is frequently found long after the shedding period is over. Nevertheless, it seems highly probable that it is a deciduous tooth which, having no successor, is not shed. In this case it would seem that the permanent tooth had been eliminated earlier in the course of evolution than the deciduous one. But until we have more conclusive evidence on this point probably it will be as well to include the "wolf" tooth among the teeth with which we find it. In figure 34*A* there is shown the unusual occurrence of the "wolf" tooth in the lower jaw. In looking over the fossil ancestors we find that this tooth began to show signs of elimination in the late Oligocene Period, which is estimated to be about nineteen or twenty million years ago. At this rate, we may reasonably hope for some few social reforms before the horse is entirely rid of this rather undesirable appendage.

PREMOLARS AND MOLARS OF THE HORSE

WHEN we compare the molar tooth with its most intricate structure, with the incisor, the latter seems perfect simplicity. Without here discussing the evolutionary history of the tooth, it is extremely interesting to consider these special adaptations, which are merely gradual modifications of a simple form brought about without any radical or sudden changes, but slowly developed in an orderly and, shall we say, orthodox manner.

The molar of the horse as we find it to-day is a wonderful structure, presenting on its grinding surface a most complicated system of sharp enamel edges almost as hard as glass, supported on one side by dentine and on the other by cement. These materials being somewhat softer than enamel wear down slightly in advance, leaving the enamel edges sufficiently exposed to give a perfect self-sharpening, grinding surface, but at the same time not projecting so far beyond the general plane as to be in danger of chipping off.

When we compare such a tooth as this with a perfectly simple one, composed of dentine and having a short, either cone-shaped or flattened crown, covered with a smooth shell of enamel, it is difficult at first sight to see any relation or similarity between them, or to realize that the highly specialized organ is simply a modification of the primitive structure. We have already shown that the incisor of the horse is a modification of the primitive tooth. Now, let us consider the more complex deciduous upper molar of a colt before there has been any wear on the

grinding surface. The crown in form is somewhat like an irregular pillar, composed of dentine with two deep depressions in the top, the dentine being completely covered with enamel, and a thick deposit of cement on the surface of the enamel.

When the cement and enamel are worn through on the grinding surface we have the exposed edge of an enamel cylinder filled with dentine, reënforced with cement on the outer surface, and two enamel pockets, with the edges exposed, imbedded in the dentine. These pockets or depressions are lined on their inner surfaces, or completely filled, as the case may be, with a deposit of cement. This is a construction similar to that we have already seen in the incisor, except that we have two instead of the single cul-de-sac, and that the enamel walls of these culs-de-sac, as well as the external enamel wall are deeply crenated or folded and doubled, in some places the inner coming almost in contact with the outer enamel, thus increasing greatly the exposed enamel edges, as shown in Fig. 35*A*. It must be borne in mind that the horse's teeth are not fully functional until the folded edges of enamel on the grinding surface are worn through to the dentine.

Figure 35*B* shows the grinding surface of a deciduous upper molar (*d. m.* ^{4}) of a colt about three months before birth. The enamel of the culs-de-sac is continuous with that of the exterior, the folded edges on the grinding surface being unworn. It is as yet entirely without cement so that we have an unobstructed view of the enamel. When the colt is six months old, however, the culs-de-sac will be practically filled with cement and also the deep folds of the exterior (Fig. 35*A*), the deposit of cement beginning about a month before birth.

We have seen that the permanent incisors are much more highly specialized than are the deciduous ones (Page 54). This is quite as noticeable in the grinding, or cheek,

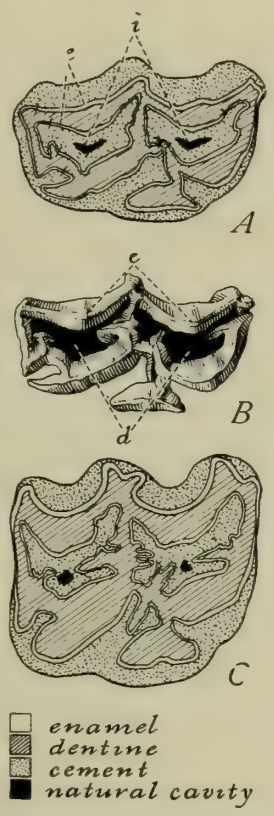


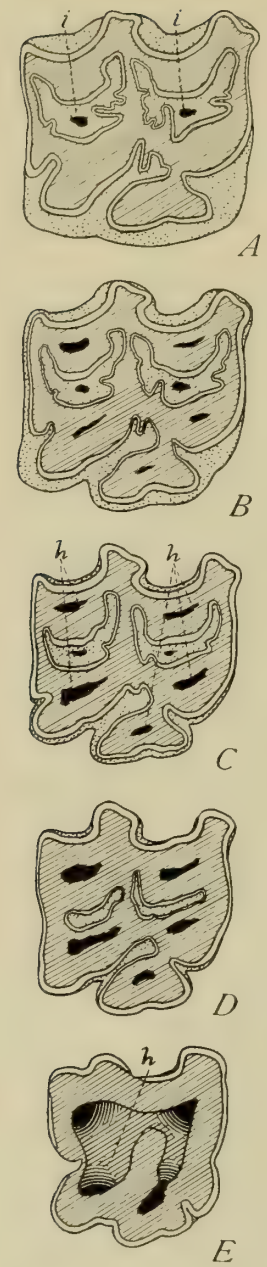
FIG. 35. WEARING SURFACE OF UPPER GRINDING TEETH.

Natural size.

A. Worn surface of deciduous molar (*d. m.*^{4}) of colt about 6 months old. *e*, exposed enamel edges; *i*, natural cavity in cement

B. Unworn surface of deciduous molar (*d. m.*^{4}) of colt about 3 months before birth, showing enamel only. *d*, cul-de-sac to be filled later with cement; *e*, apex of folded edge of enamel

C. Premolar (*p. m.* ^{3}) of horse 8 or 9 years old



teeth. Observe the wonderful development of enamel edges in figure 35*C* as compared with *A*. *C* is a premolar of a horse eight or nine years old. A careful measurement of the exposed enamel in this tooth reveals the interesting fact that, if these edges were straightened out in a continuous line, it would be fourteen inches in length. In a tooth of this size on the simple "cylinder" plan, it is obvious we would have only about four inches of enamel, hence we can willingly concede nature's wisdom in this comparatively "modern improvement."

This enamel pattern, however, presents a more simple aspect as the tooth wears down toward the base of the crown, so that in old age when the grinding surface is near the root, there is less enamel, and the self-sharpening surface is much less perfect. The antero-posterior diameter of the crown is also reduced toward its base. Figure 36 shows an upper right grinder (*p. m.* $\frac{4}{4}$) of a horse ten or eleven years old. The tooth is cut in five sections, and reveals on each cut surface the pattern of enamel which will be presented on the naturally worn grinding surface at various ages.

Section *A* is a diagram of the natural grinding surface as it appeared in life, and shows a very complicated pattern of enamel, and large culs-de-sac almost completely filled with cement.

Section *C* which is cut one and one-fourth inches farther along the crown, a point that would be reached by natural wear at about twenty-five years, shows great simplification of enamel pattern, and the culs-de-sac are much smaller than in *A* and *B*. The five branches of the pulp cavity (*h*) are open, but in life

FIG. 36. UPPER GRINDER (P.M.$\frac{4}{4}$) OF HORSE 10 OR 11 YEARS OLD

Cut in 5 sections; showing pattern of enamel at various ages.

A. *i*, Natural cavity in cement
C. *h*, Branches of the pulp cavity
E. *h*, Pulp cavity

would have been filled with new dentine before the natural grinding surface reached this point.

Section *E*. The lower border of enamel which marks the base of the crown where this section is cut is somewhat irregular, so that the enamel line is incomplete. This explains the three spaces which can be seen in the external enamel. The culs-de-sac are entirely eliminated and the enamel edges are reduced to a minimum. The branches of the pulp cavity are united at this point (*h*), where the roots begin to diverge. The diameter of the tooth is also greatly reduced. This tooth, *p. m.* $\frac{4}{}$, being the youngest in the grinding set, would not be worn down to the base of the crown until the horse reached thirty-five or more years, an age rarely attained. Sections of grinding teeth on exhibition, particularly specimen No. 95, will be of interest as illustrating structure and wear.

The lower molars in their construction are similar to the uppers, though there are some obvious differences, the most striking one being the absence of the culs-de-sac. Much the same result is acquired, however, by the very deep folding in of the external enamel, which at several points almost meets toward the center (Fig. 37). The lower molars are also narrower in their transverse measurement, which would seem to shorten their period of wear. This lesser width, however, is counteracted by a greater length of crown, so that the period of service is about equal to that of the uppers.

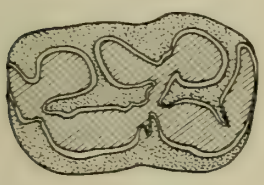


FIG. 37. LOWER PREMOLAR (P M.) OF HORSE 8 OR 9 YEARS OLD

There are several points which sometimes lead to a little confusion in observing the wearing surface of the grinding teeth. For example, at the bottom of the deeper concave surfaces of dentine between the enamel walls, there is a dark brown mark which is sometimes mistaken for a fourth material, but is merely a coloration of the dentine.

In the upper grinders we generally find two small cavities (Fig. 35*A* and *C*), one in each cul-de-sac, which sometimes give rise to questionings; and indeed there have been swindlers masquerading as veterinary dentists, who would gladly "fill" your horse's teeth for a reasonable consideration. These cavities, however, are perfectly normal, as already explained, their presence or absence depending simply upon the thickness of the cement.

It will be seen that where the tooth comes in close contact with its next neighbor, the cement is missing, and indeed, sometimes the continuous line of external enamel is broken (Fig. 37). This is due to a

slight wear on the side of the tooth. There is a strong tendency to crowd toward each other, thus preventing the forcing of food material between them. The slight vibration, when in use, of each tooth in its alveolar socket affords sufficient wear to keep them perfectly fitted together, and also explains the apparent break in the external enamel wall, which we frequently see. This crowding together, as well as many other features, can best be observed from the side view as shown in a series of skulls, on exhibition, with the bone cut away in order to expose to view the full length of the teeth.

The posterior teeth, or molars, incline very considerably to the front, while the premolars lean slightly toward them (Fig. 39), so that when pressure is applied on their grinding surfaces they are forced together like stones in the arch of a building. And as the teeth wear down to a point of smaller diameter, the lower molars in extreme old age incline more toward a horizontal position, particularly m_3 (Fig. 39*C*).

The grinders from a lateral view present a most formidable looking dental battery. It gives some idea of their development when we find that a full set of premolars and molars, taken from a fair-sized horse of four or five years, will weigh about four pounds, the premolars being heavier and more highly developed than the molars, a fact which is quite unusual, as in the great majority of mammals the premolars are very much inferior in size and development, as was also the case in the ancestral horse.[1]

We see, from the lateral view as well as from the grinding surface, the more highly specialized character of the permanent teeth. Compare the very long crowns of figure 39*A* with the deciduous molar (Fig. 38), with its short crown, clearly defined base line, and flaring roots.

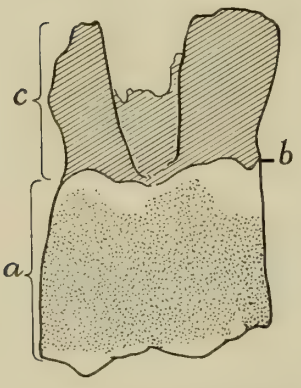


FIG. 38. DECIDUOUS MOLAR (D. $M.^3$) OF COLT 11 MONTHS OLD

Natural size. *a*, crown; *b*, base of crown; *c*, root

Wear and movement of premolars and molars can be studied very readily from the skulls on exhibition, three of which are shown in figure 39.

For the present we will consider only the lower teeth, which will apply in a general way to the upper as well. The calcification of the tooth begins at the grinding surface, inside the alveolar cavity, and proceeds toward the root, the tooth constantly moving upward, erupting and beginning to wear off before even the crown is complete.

[1]See page 15.

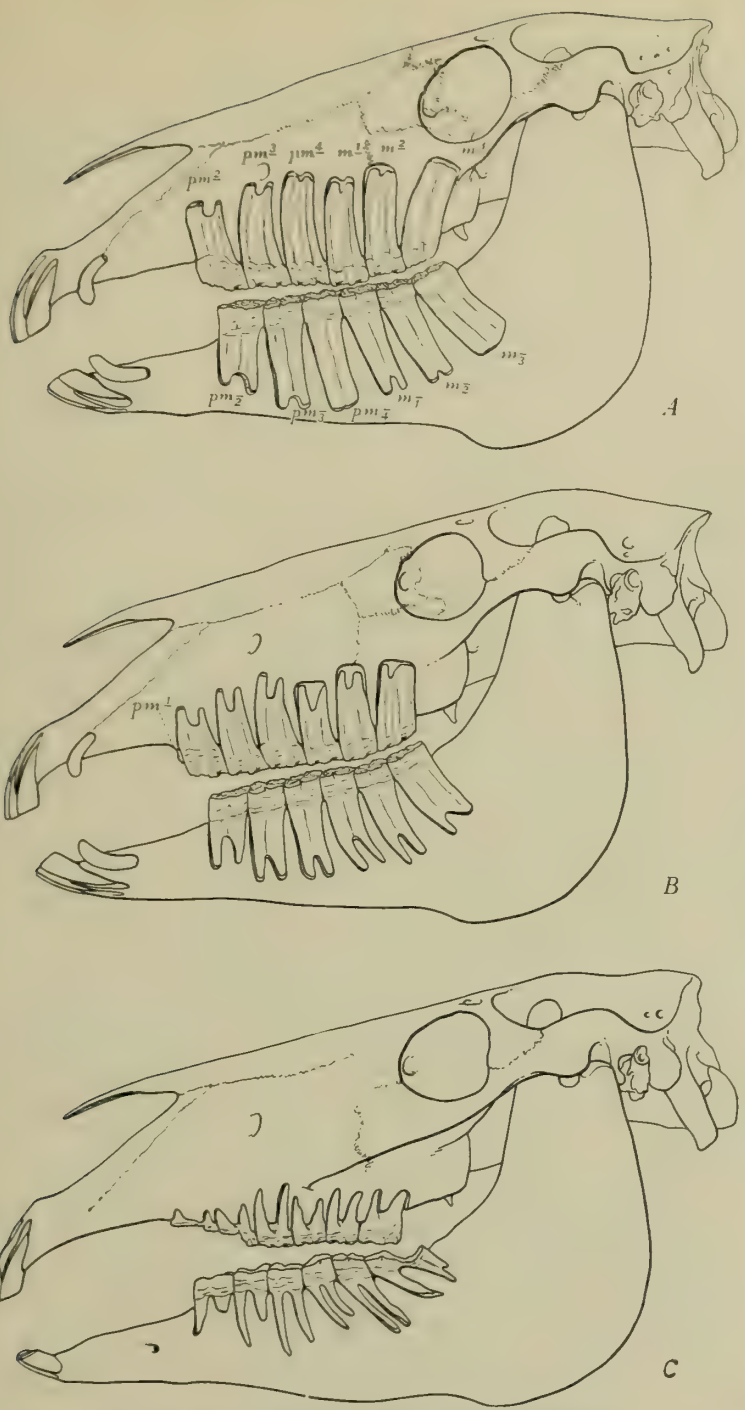


FIG. 39. DENTAL BATTERY OF ADULT HORSE

A. Skull 5 years old. Permanent teeth all in use. Specimen No. 26 ♂
B. Skull 8 years old. Crowns reduced in length by wear and roots grown longer. Vestigial $p.m.\frac{1}{1}$ present in this individual. Specimen No. 22 ♂
C. Skull 39 years old. Crowns almost worn away. Lower molars incline forward. Canines absent. Specimen No. 40 ♀

Figure 39*A* shows the skull of a horse about five years old. The deciduous set has been shed and the permanent teeth are all in use, though the "wolf" tooth ($p.\ m.\ \frac{1}{1}$) is not present in this specimen. The crown of $p.\ m.\ \frac{4}{4}$, the last tooth in the grinding set to reach the wearing line, has just completed its growth, having already lost about half an inch from wear. There now remains a length of three and a half inches to be slowly moved upward and worn away should the horse live to an extreme old age. The roots are just beginning to develop at the base of the crown. The next tooth back of this, $m.\ \frac{1}{1}$, is the first permanent tooth to appear, hence the oldest one in the mouth. The crown is worn down much shorter than that of $p.\ m.\ \frac{4}{4}$, and the roots are quite evident, though still incomplete.

In figure 39*B*, showing a specimen about eight years old, the crowns have all been perceptibly reduced by wear, and the roots are all more or less developed, those of $m.\ \frac{1}{1}$, being almost completely grown.

The oldest skull[1] in our exhibit is a specimen from a horse thirty-nine years old, (Fig. 39*C*). Several of the crowns are worn down to the roots, while the others have but little grinding material in reserve. Some of the roots are very much elongated, while others are thickened by an extreme reënforcement of cement. The molars are very much inclined forward, particularly $m.\ \frac{3}{3}$, which is so worn as to almost separate the two roots. In the upper set, $p.\ m.^{\frac{2}{2}}$ is represented only by irregularly shaped lumps of cement which surround the last fragments of roots, prolonging to the utmost their very much impaired service.[2]

ERUPTION OF THE TEETH OF THE HORSE

THE calcification of all the deciduous teeth and also of $m.\ \frac{1}{1}$ begins before birth. When the colt is born, $d.\ i.\ \frac{1}{1}$ and $d.\ m.\ \frac{2}{2}$ and $\frac{3}{3}$ are very near the surface of the gum, and generally erupt within two or three days; $d.\ m.\ \frac{4}{4}$ is apt to follow during the first month; the next tooth will be $d.\ i.\ \frac{2}{2}$, which appears between the fourth and sixth months; $d.\ i.\ \frac{3}{3}$, the last deciduous tooth to erupt, makes its appearance as late as the eighth or tenth month.

When we examine (Fig. 40*A*) a skull before birth at about the fifth or sixth month of fœtal life, we find that the space occupied by the deciduous molars in their alveolar cavities seems out of all proportion to the length of the skull, so that $d.\ m.\ ^{\frac{2}{2}}$ and $d.\ m.\ ^{\frac{3}{3}}$ occupy as great a proportion

[1]Since writing, a skull 42½ years old has been obtained, Specimen No. 138 on exhibition.

[2]Specimen No. 132 in wall case shows interesting examples of reënforcement by cement in extreme old age.

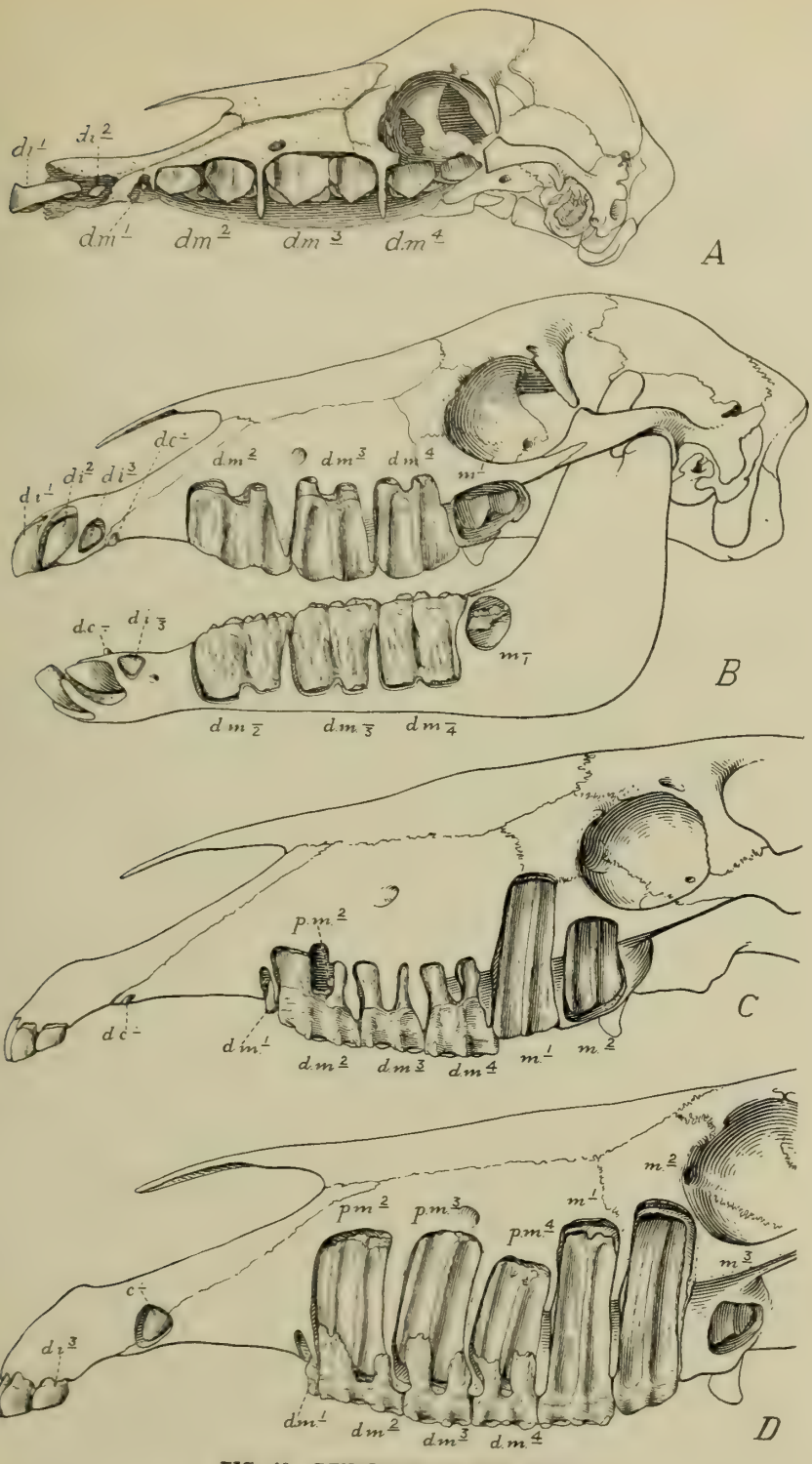


FIG. 40. DENTITION OF THE COLT

A. The 5th or 6th month of fœtal life. ½ Natural size. Specimen No. 2 ♂

B. Colt 2 days old showing deciduous teeth and early stage of m. $\frac{1}{1}$. ½ Natural size. Specimen No. 35 ♂

C. 11 months old. Deciduous teeth somewhat worn and permanent set developing. ½ Natural size. Specimen No. 38 ♀

D. 2 years old. Deciduous teeth very much worn and permanent set partly in use. ½ Natural size. Specimen No. 49 ♂

of the length of the skull as will finally accommodate the whole grinding set of the adult horse. Consequently *d. m.* $\frac{4}{}$ is crowded far back, beginning its development in the alveolar cavity directly below the eye socket, as shown in figure 40*A*. This discrepancy, however, is nicely adjusted. As fast as the increasing size of the skull will permit, the teeth are crowded forward with a horizontal movement, making room at the back for the development of the molars, each one in turn resigning its birth-place below the eye, and moving forward to make room for the next one to fall in line, the operation being about the same in the lower set as in the upper teeth. It will also be seen that *d. i.* $\frac{1}{}$ projects beyond the present border of the muzzle. At this early stage the bone is incomplete but will surround the young tooth a little before birth. In the mean time, the tooth is protected by soft tissue.

The incisors also encroach upon the region of the very small *d. c.* $\frac{}{}$ particularly *d. i.* $\frac{3}{}$, which begins its development well back of the *d. c.* $\frac{}{}$ (Fig. 40*B*), a colt 2 days old. With the elongation of the jaw *d. i.* $\frac{3}{}$ passes forward and assumes its final position in front of *d. c.* $\frac{}{}$.

At eleven months (Fig. 40*C*) the deciduous teeth are all in use and most of them considerably worn. *m.* $\frac{1}{}$, which is due to erupt within about a month, has increased wonderfully in length and has moved forward, giving up the place under the eye to *m.* $\frac{2}{}$, which has already attained considerable size, and has advanced somewhat in its forward movement. Between the roots of *d. m.* $\frac{2}{}$, which are flattened and widely spread apart, thus making room for the new tooth, the calcification of *p. m.* $\frac{2}{}$ is just beginning. *i.* $\frac{1}{}$ is developing, and can be seen in specimen No. 38[1] far back in the alveolar cavity under the root of *d. i.* $\frac{1}{}$, but is not visible in the figure.

In figure 40*D*, a colt of two years, calcification has begun in all the permanent teeth except *i.* $\frac{3}{}$. The crowns of the deciduous molars are nearly worn away, while the roots are being absorbed by the growth of the premolars which have now attained a considerable size. *m.* $\frac{1}{}$, the first permanent tooth to erupt, has been in wearing about a year and is just beginning to develop roots. *m.* $\frac{2}{}$ has cut through the gum and is very slightly worn. The upper end of this tooth seems to be shooting upward in dangerous proximity to the eye socket but, fortunately for the young colt's outlook upon life, will move forward just in time to escape a collision. The alveolar cavity below the eye is now lodging its last young tenant, *m.* $\frac{3}{}$, which will erupt at about four years and by the time it is full grown will be nearly two inches anterior to its present position. However, in considering changes in a growing skull, it is

[1]On exhibition in wall case.

difficult or impossible to locate any fixed point, as there is so much readjustment throughout life, particularly during the rapidly growing period of immaturity. But, if we arbitrarily make our measurements from the center of the orbit, we find that *p. m.* $\frac{4}{4}$, in a mature skull of average size, is seven inches anterior to the point directly below the eye socket which gave rise to its deciduous predecessor, *d. m.* $\frac{4}{4}$, (example Fig. 39*B*).

SHEDDING THE TEETH

BEFORE the deciduous molars are shed the crowns are almost entirely worn away on the grinding surface, while the roots are absorbed by the new teeth at the base, so that there is only a small fragment of tooth really lost. The time of shedding may vary a number of months: At approximately three years *d. m.* $\frac{2}{2}$ and $\frac{3}{3}$ are shed, exposing the grinding surfaces of *p. m.* $\frac{2}{2}$ and $\frac{3}{3}$. *m.* $\frac{1}{1}$ and $\frac{2}{2}$ are in use and somewhat worn. At about three and one-half years *d. i.* $\frac{1}{1}$ will be shed. At four the shedding of *d. m.* $\frac{1}{1}$ follows very closely after, or sometimes during the eruption of *m.* $\frac{3}{3}$. A little later *d. i.* $\frac{2}{2}$ are shed. At about five or a little before the canines will erupt and *d. i.* $\frac{3}{3}$ are shed, and the permanent dentition is all in use. There are a number of specimens on exhibition in the wall case, not figured in this description, which it would be well to consult in connection with the shedding of teeth.

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Our Common Butterflies

Y F. E. Watson and F. E. Lutz

OUR COMMON BUTTERFLIES

BY

F. E. Watson & F. E. Lutz

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OUR COMMON BUTTERFLIES

By F. E. Watson & F. E. Lutz

IN THIS CASE "OUR" REFERS TO THE VICINITY OF NEW YORK CITY, ALTHOUGH MOST OF THESE SPECIES ARE WIDELY DISTRIBUTED. HAUNTS, FOOD-HABITS, AND LIFE HISTORIES ARE GIVEN IN TABULAR FORM FOLLOWING THE TEXT.—*The Editor.*

THE graceful flight and beauty of adult butterflies have made them the most popular insects, but in their youth they have in the eyes of many people little beauty and can only crawl and eat. They are "horrid caterpillars," poisoned by gardeners and shunned by all except the few who see in them the possibilities of maturity. However, not all caterpillars develop into butterflies; the greater number become moths, and some creatures which strongly resemble caterpillars are really quite different from either butterflies or moths.

A useful distinguishing characteristic of insects is the possession of three pairs of true legs. Nothing else which the amateur is likely to notice has just this number. Spiders have four pairs and centipedes have many; they are not insects. Now a caterpillar *appears* to have more than three pairs of legs, but it will be seen upon close examination that the three front pairs are the only ones which are jointed. The other "legs" are not true legs but merely fleshy props. Young leaf-feeding beetles do not have these props and young saw-flies (relatives of wasps) have five or more pairs in the middle of the body, whereas young butterflies have four pairs and a pair of claspers at the hind end of the body.

When young Lepidoptera have once eaten their fill, they cast off the skin they have been wearing and get a larger one. This process is repeated three or four times, and finally they are full-grown caterpillars. Then, if

AN AJAX SWALLOWTAIL CATERPILLAR. Note the two kinds of legs, thoracic and abdominal

they are young moths, they seek a suitable place and usually spin a cocoon of silk threads. Inside of this they molt once more, but instead of becoming a larger caterpillar each turns into a mummy-like pupa. If they are young butterflies, the fundamental process is the same but usually no cocoon is made. The pupa, which is also called a chrysalis, hangs naked. Perhaps the single thread around the body of some of them and the silk which fastens the tail to

the supporting surface represent the moth's cocoon.

The distinction between adult moths and adult butterflies is largely a matter of habits and "feelers." The antennæ are a pair of appendages on an insect's head which are popularly called "feelers," although, as a matter of fact, insects smell and possibly hear with their antennæ as well as feel. The antennæ of butterflies are threadlike and have a knob or swelling at the tip. The antennæ of many moths are clearly feather-like. In others the plumules are not visible to the naked eye and the antennæ look like threads but they almost never have a swelling at the end large enough to be confused with the knob of butterflies. Then, too, all our butterflies fly only in the daytime, while all but a very few of our moths fly only at night.

SWALLOWTAILS

These are the giants of our northern day-fliers and belong to the genus *Papilio*. The conspicuous resemblance of their hind wings to the "swallowtails" of the sartorial art and their large size distinguish them from all of our other Lepidoptera except the pale-green night-flying Luna. The *Papilio* which is largely yellow and has, among other black markings, three or four short black bands on the front half of each front wing is the Tiger Swallowtail. Sometimes the female of this species has the yellow replaced by sooty brown except for the marginal spots. This form is rare with us but is quite common in the South.

The Parsley Swallowtail is about as common as the Tiger. Its young feed on parsley, carrot, celery, and parsnip leaves. The adult male may be recognized by the row of yellow spots across the middle of the wings. These spots are sometimes much reduced in the female. The row of blue spots, inside the marginal yellow ones, is more distinct in the female than in the male.

The Spicebush Swallowtail, our commonest species, has a single or at most an incomplete second row of greenish-white spots on the front wings. The hind wings are usually suffused with greenish in the male and bluish in the female. Its larvæ feed on sassafras and spicebush leaves.

WHITES

A white butterfly is a common sight and a guess that it is *the* Cabbage Butterfly (*Pieris rapæ*) will almost always hit the mark. There are really three kinds of white butterflies in the Northeast whose young feed on cabbage and allied plants. Two of them are natives, but the third was accidentally brought from Europe to the vicinity of Quebec about 1860. Since that time, aided doubtless by further importations, it has spread over the whole country and, like its compatriot the English sparrow, it has largely replaced its native relatives in the more densely populated regions. This invader, known as the European Cabbage Butterfly, has the tips of the upper side of the front wings black; there are two black

TIGER SWALLOWTAIL (*Papilio glaucus*)
Male, above; female, form *turnus*, below

WHITES AND YELLOWS

From above downward.—CABBAGE BUTTERFLY (*Pieris rapæ*); male, left, and female. MUSTARD WHITE (*Pieris virginiensis*). CHECKERED WHITE (*Pieris protodice*); male, left, and female. FALCATE ORANGE-TIP (*Anthocharis midea*); male, left, and under side. LITTLE SULPHUR (*Eurema lisa*); male, left, and under side

REGAL FRITILLARY (*Spyeria idalia*); male, above, and under side

spots on each of the front wings of the female and one on those of the male; the under side of the hind wings is yellowish and without markings.

With us the Mustard White, or Immaculate Cabbage Butterfly, has practically no markings on the upper surface of the wings, although in other parts of the country it is subject to many interesting variations.

The Checkered White, or Southern Cabbage Butterfly, has no definite black tips to the front wings, but it has two or three distinct black spots on the upper surface of each in the male and many dusky spots in the female.

There is a pretty little White that may be recognized by the green marbling on the under side of the hind wings. It is called the Falcate Orange-tip from the shape and color of the front wings, although only the males are orange-tipped.

(See also the next section.)

GREAT SPANGLED FRITILLARY (*Spyeria cybele*); male, above, and under side

YELLOWS

Several species of yellow butterflies are closely related to the Whites just described. They nearly all feed on clover and its allies. It should be remarked parenthetically that when the food of a species is mentioned we mean the food of its young, for adult butterflies do not eat solid food. At most they sip water from wayside pools or nectar from flowers through a coiled tubelike mouth which entirely lacks teeth or even jaws.

The most common Yellow in the Northeast is the Clouded Sulphur. It may be distinguished from the Little Sulphur by its size and by the presence of a silvery spot on the under surface of each hind wing. Occasionally the normally yellow color of the Clouded Sulphur becomes white in the females but the silvery spots differentiate it from the Whites.

THE FRITILLARIES

Three of our Fritillaries have a wing expanse of at least two inches.

SMALLER SPANGLED FRITILLARY (*Spyeria aphrodite*); male, above, and under side

They are tawny or tawny-red above, variously studded with silvery white spots below. The upper surface of the hind wings of the Regal Fritillary is nearly black but the base is tawny and there are two rows of light spots. The outer row of these spots is tawny in the male, both rows being whitish in the female. The Great Spangled and Smaller Spangled have no white markings on the upper surface and the wings are darker at the base than elsewhere although not at all black except for spots and irregular bands. It is difficult to distinguish between these two species, the chief difference being on the under side of the hind wings, which in the Great Spangled have a much wider and paler yellow band than in the Smaller Spangled. The latter is the smallest of the three. All of them feed upon violets, as do the Meadow and the Silver-bordered, their smaller relatives. The last two species are very similar on the upper side but on the under side the Meadow does not have any silvery spots

From above downward (under sides on the right).—SILVER-BORDERED FRITILLARY (*Brenthis myrina*); MEADOW FRITILLARY (*Brenthis bellona*); PEARL CRESENT (*Phyciodes tharos*); and the BALTIMORE (*Euphydryas phaëton*)

The Pearl Crescent, which feeds upon asters, should be considered with the last two mentioned, for each has the upper side tawny, closely checkered with black. The under side of the Pearl Crescent is yellowish mottled with brown, a whitish crescentic spot near the middle of the hind margin being usually present and frequently accompanied by other similar spots.

The Baltimore has the ground

From above downward (under sides on the right).—VIOLET TIP (*Polygonia interrogationis*); HOP MERCHANT (*Polygonia comma*); and GRAY COMMA (*Polygonia progne*)

color of both wings black, bordered with orange-red spots within which are two or three rows of white spots. The under side is similar to the upper but with additional spotting. This butterfly is subject to great variation. During the season in which they are born the caterpillars are gregarious, living within a web with which they envelope their food-plant, the Turtle-head and, less commonly, allied plants. After molting three

SWALLOWTAILS

and (above) their less ornate relative, the CLOUDED SULPHUR (*Colias philodice*, under side on the right). Just below are the male (left) and female Parsley Swallowtail (*Papilio astrius*). Finally, we show the male (left) and female SPICEBUSH SWALLOWTAIL (*Papilio troilus*)

THREE COMMON VANESSAS

The upper sides are shown on the left; the under sides on the right. From above down they are the RED ADMIRAL (*Vanessa atalanta*), HUNTER'S BUTTERFLY (*Vanessa virginiensis*), and the THISTLE BUTTERFLY (*Vanessa cardui*). Each of these was formerly put in the genus *Pyrameis* instead of *Vanessa*

MOURNING CLOAK (*Nymphalis antiopa*); upper, above, and under side

times, the whole colony hibernates within the web, made more dense for the purpose. In the following spring, they leave the web, disperse and feed upon a great variety of plants.

ANGLE-WINGS

The Angle-wings "look as if Mother Nature had with her scissors snipped the edges of their wings, fashioning notches and points according to the vagaries of an idle mood." The wing expanse is about two inches and, while the upper surface is tawny, variously marked, the under surface is a combination of brown and gray which corresponds so closely with the color of dead leaves that an Angle-wing at rest on the forest floor is extremely well hidden.

The Violet-tip has a tail suggestive of the Swallowtails. The upper surface of this tail and the adjacent marginal portions of the hind wing are tinged with violet. On the under

side of each hind wing there is a pair of silvery markings which are somewhat like an interrogation point. The young feed on elm leaves.

The Hop Merchant or Comma has a silvery comma or parenthesis on the under side of each hind wing and there is considerable yellowish color on the under surface of both pairs of wings. The first name here given refers to a feeding habit of the young but wood-nettle is preferred as a food-plant to hops.

cies can be recognized most easily by the brilliant red band crossing each front wing.

Eye-spots are very distinct on the under surface of the hind wings of Hunter's and the Thistle Butterflies. For some strange reason, these butterflies but more particularly the latter, are also called Painted Lady or Painted Beauty. The Thistle is one of the most widely distributed of butterflies—as widely as the thistles on which it feeds. There are usually four

BUCKEYE (*Junonia cœnia*); upper, left, and under sides

The Gray Comma or Progne has a silvery marking similar to that of the Comma but smaller, and the under surface lacks yellow. Its young prefer the leaves of currant and gooseberry.

The Angle-wings hibernate as adults.

VANESSAS

The Red Admiral has "eye-spots" (circular spots surrounded by one or more rings of a different color) on the under side of the hind wings but they are usually very indistinct. This species can be recognized most easily by the brilliant red band crossing each front wing.

eye-spots on each hind wing, below, these spots being smaller than the two, similarly located, of Hunter's.

The Mourning Cloak or, as the English call it, the Camberwell Beauty, is blackish with light margins underneath, and deep purplish edged with yellow above. Its spiny young feed on willow, poplar, elm, and the like.

The Buckeye has a narrow orange band near the border of its brown wings. Each front wing is ornamented with a whitish transverse

"RULERS"
From above downward.—MONARCH (*Danaus plexippus*); VICEROY (*Basilarchia archippus*) and BLUE EMPORER (*Basilarchia astyanax*)

band and a large eye-spot. The hind wing has two similar eye-spots. Beneath, the front wings are similar to the upperside but duller in color. The

Common WOOD-NYMPH (*Minois alope*), above; COMMON GRASS-NYMPH (*Satyrodes eurydice*), left; and LITTLE WOOD-SATYR (*Megisto cymela*)

hind wings are grayish, brownish, or reddish, with the eye-spots represented by mere spots or dots.

Some Vanessas hibernate, like the Angle-wings, as adults, hidden away under a pile of fence rails, in a hollow log or in some such nook.

THE "RULERS"

The Monarch, or Milkweed Butterfly, during early autumn assembles in great swarms in the northeastern United States, large numbers hanging quietly from the leaves and branches of trees and shrubs. These flocks then move southward, suggesting the migration of birds. It is believed, but not positively established, that there are return migrants in the spring. At any rate, none of us has ever found the Monarch in the North during the winter. Its black and yellow banded larvæ with their long flexible "horns," and its gold-dotted delicate bluish-green chrysalis are as easily recognized as the adult.

The Viceroy resembles to an astonishing degree the common and wide-spread but not closely related Milkweed or Monarch Butterfly. Its general color is a tawny red; the wing veins are outlined in black, and there is a white-spotted black margin to the wings. So far, the description will fit either species, but the Viceroy has a narrow black band across the middle of the hind wings which the Monarch lacks. Like other members

From above downward (under sides on the right.)—GRAY HAIR-STREAK (*Strymon melinus*). CORAL HAIR-STREAH (*Strymon titus*). BANDED HAIR-STREAK (*Strymon falacer*)

of its genus (*Basilarchia*), it hibernates as a small larva in a silken-lined tube formed of part of a leaf of the food-plant and attached to a twig by silk.

The Blue Emperor is also called the Red-spotted Purple, the red spots being at the apex of the front wings on the upper side but more scattered on the lower side. This is, perhaps, our most beautiful butterfly and is subject to great color variation. Some individuals have the red spots on the upper side entirely wanting. In others there is a distinct greenish cast, especially to be noted on the hind wings. It has also a very rare form, *albofasciata*, so called because of the white band on both fore and hind wing. This form closely resembles the White Admiral of the Catskills and northward, but white-banded specimens taken in the vicinity of New York City are *albofasciata.*

THE EYED BROWNS

The common Nymphs have eye-spots on the upper side of the front wings. The general color is brownish-gray. That of the Common Wood-

From above downward.—AMERICAN COPPER (*Lycæna hypophlaeas*); male, left, and under side. TAILED BLUE (*Everes comyntas*); male, left, and under side. COMMON BLUE (*Lycænopsis pseudargiolus*); male, left, and female; below them three showing variations of under side

nymph is dark but the eye-spots of the front wings are set in a yellowish band. There are not usually more than two, if any, spots on the upper surface of each hind wing.

The Common Grass-nymph has a row of four small spots on the upper surface of each front wing and the Little Wood-satyr has but two. The brown of both is rather pale and both have the spots on the upper surface of the hind wings "eyed."

HAIR-STREAKS, COPPERS, AND BLUES

We can give only a few examples of this large family of small and often brilliant butterflies. The legs of the slug-shaped caterpillars are so shortened that these creatures seem to glide rather than crawl. The larvæ of many species secrete a sweetish fluid which is eagerly gathered by ants and the larvæ will usually be found with one or more ants in attendance. Of the

From above downward.—SILVER-SPOTTED SKIPPER (*Epargyreus tityrus*), upper and under sides. Left, SOOTY-WING (*Pholisora catullus*); right, LEAST SKIPPER (*Ancyloxypha numitor*). Males, left; females, center; under sides, right: TAWNY-EDGED SKIPPER (*Polites themistocles*); YELLOW-SPOTTED SHIPPER (*Polites peckius*); VOLCANIC SKIPPER (*Catia otho egeremet*)

species mentioned below, the larvæ of the Coral Hair-streak feed at night, and during the day remain beneath the surface of the ground in ants' nests at the foot of the food-plant. Their chrysalis is also formed there.

The Gray Hair-streak has the upper side of both wings slate-gray, with an orange patch on each hind wing. Beneath, the wings are light

From above downward.—MORMON SKIPPER (*Poanes hobomok*); male, left, and under side; usual female, left, and the female variety *pocahontas*. LITTLE GLASS-WING (*Polites verna*); male, left; female, center; and under side

gray with two dark, white-edged lines in addition to the orange patches. Each hind wing is also provided with a long threadlike tail.

The Coral and Banded Hair-streaks are brown on the upper and under sides of their wings and without markings above, except for the oval sex marks on the males. Below, the Banded has two narrow blue bands, and, on each hind wing, one or two orange patches, a blue patch, and a threadlike tail; the Coral has a row of black dots near the center, and a band of coral-red spots (sometimes absent on the front pair) along the margin of each wing.

The American Copper has its front wings coppery-red with some black spots. Its hind wings are brownish with a coral-red border. The under side is similar but much paler.

The Tailed Blue is a delicate little creature which has tails that may be seen by looking closely, but it is apt to be confused with the Common Blue—its extremely variable relative. Each of them has several generations a year, although the latter is frequently called the Spring Azure on account of its abundance when other butterflies are scarce.

THE SKIPPERS

These butterflies, belonging to the family Hesperiidæ, get their common

name from their rapid, darting flight. They are, for the most part, small and dull-colored. The sexes of some species differ in the markings on the upper side.

The Silver-spotted Skipper may be recognized by the large silvery spot on the under side of the hind wings. It is extremely pugnacious and will dash at any insect which flies near it.

The Sooty-wing has nearly black wings, the front pair with some minute white dots; the female has additional indistinct white dots on the hind wing. The under side is similar but paler.

Numitor is called the Least Skipper because of its small size. Its wings are tawny and dark brown. The front wings are generally dark above but have a light front margin below.

The Tawny-edged Skipper has the front wings in the male tawny with a brown border and the hind wings brown. The female has brown wings with a few tawny spots on the front pair, which also have a tawny upper edge in some specimens. Beneath, the front wings are similar but paler; the hind wings are dull greenish-yellow with an indistinct band of minute whitish dots across their centers.

The Yellow-spotted Skipper has bright yellow spots, as shown in the figure, on a brown ground color. These are brighter and larger on the under side of the wings. Other species have similar colors but the pattern is different.

The Volcanic Skipper is dark brown with a few yellow spots on the front wing. The under side is similar to the Tawny-edged, but darker, with the band on the hind wings more distinct.

The Mormon Skipper has two female forms. The typical one is tawny orange with dark brown borders; the other (variety *pocahontas*) is dark brown with white markings. This variety is less common than the typical form.

The Little Glass-wing has dark brown wings with whitish-translucent spots on the front pair. The under side is similar to the Volcanic, but the spots are whitish, not yellow.

In addition to those already mentioned, there are about twenty other species which are rather common in this vicinity, but longer and more technical descriptions than can be given here would be necessary for their identification. They are, for the most part, Hair-streaks and Skippers, small brownish or brown and yellow creatures which flit before our eyes and then, aided by their concealing colors, disappear.

EXPLANATION OF FOLLOWING TABLES:

E=EGG. L=LARVA (caterpillar). P=PUPA. A=ADULT. The "calendar" will vary somewhat with locality and weather.

TABLE OF LIFE HISTORIES

NAME	NOV. TO MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	PREFERRED FOOD-PLANT	HAUNTS
Tiger Swallowtail	P	PA	AEL	LP	AEL	AELP	AELP	P	Wild Cherry	Open Fields and Woods
Parsley Swallowtail	P	P	AEL	LP	AEL	AEL	AELP	LP	Wild Carrot	Open Fields, Meadows
Spicebush Swallowtail	P	PAE	AEL	LP	AEL	ALP	AELP	LP	Sassafras	Open Fields, Woods, Meadows
Cabbage Butterfly	P	PAE	AEL	PAEL	AELP	AELP	AELP	ALP	Cabbage	Gardens, Open Fields
Mustard White	P	AE	AEL	LPA	AELP	LPAE	AEL	LP	Two-leaved Toothwort	Open Woods, Wood Roads
Checkered White	P	AE	AEL	PAEL	AELP	AELP	AELP	ALP	Wild Peppergrass	Open Fields, Waste Places
Falcate Orange-tip	P	AE	AEL	LP	P	P	P	P	Lyre-leaved Rock-cress	Open Woods
Clouded Sulphur	LP	PA	AEL	AELP	LPAE	AELP	LPAE	AEL	Clover	Open Fields, Meadows
Little Sulphur	?	?	?	AELP	AELP	AELP	AELP	A	Sensitive Pea	Open Sandy Fields
Regal Fritillary	L	L	L	LP	PA	AE	AEL	L	Violet	Wet Meadows
Great Spangled Fritillary	L	L	L	LPA	PA	AE	AEL	L	Violet	Wet Meadows
Smaller Spangled Fritillary	L	L	L	LPA	PA	AE	AEL	L	Violet	Wet Meadows
Silver-bordered Fritillary	L	LP	PAE	AELP	LPAE	LPAE	AEL	L	Violet	Wet Meadows
Meadow Fritillary	L	LP	PAE	AELP	LPAE	LPAE	AEL	L	Violet	Wet Meadows
Pearl Crescent	L	LP	AEL	AELP	PAEL	AELP	AEL	AL	Aster	Open Fields, Meadows
Baltimore	L	L	LPA	LPAE	LPAE	L	L	L	Turtle-head	Wet Meadows & Marshes
Violet-tip	A	A	AEL	AELP	AEL	AELP	LPA	PA	Elm	Open Woods, Lanes, Roads
Hop Merchant	A	A	AEL	AELP	AEL	AELP	LPA	A	Wood Nettle	Open Woods, Lanes, Roads
Gray Comma	A	A	AEL	AELP	AEL	AELP	LPA	A	Currant	Open Woods, Lanes, Roads
Red Admiral	PA	A	AEL	AELP	PAEL	LPA	PA	PA	Nettle	Wood Roads, Lanes
Hunter's Butterfly	PA	A	AEL	AELP	PAEL	LPA	LPA	PA	Sweet or White Balsam	Open Fields, Meadows
Thistle	?	?	AEL	AELP	PAEL	LPAE	PAEL	PA	Burdock	Open Fields, Waste Places

TABLE OF LIFE HISTORIES

NAME	NOV. TO MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	PREFERRED FOOD-PLANT	HAUNTS
Mourning Cloak	A	AE	AEL	LP	AEL	LPAE	AELP	LPA	Willow, Elm	Open Woods, Lanes
Buckeye	?	?	AEL	AELP	PAEL	PAEL	AELP	LPA	Gerardia	Open Fields & Roads
Monarch	Absent	Absent	AEL	LP	AEL	AELP	LPA	A	Milkweed	Open Fields, Meadows
Viceroy	L	L	LP	AELP	AEL	ELPA	AEL	L	Willow	Damp Places, Meadows
Blue Emperor	L	L	LP	LPAE	AEL	LPAE	AEL	L	Wild Cherry	Lanes, Orchards
Common Wood-nymph	L	L	L	LP	PA	AEL	AEL	L	Grasses	Grassy Meadows
Common Grass-nymph	L	L	L	LPA	PAE	AEL	L	L	Grasses	Wet Meadows, Swamps
Little Wood-satyr	L	L	PA	AEL	AEL	L	L	L	Grasses	Grassy Places, Edges of Woods
Gray Hair-streak	P	P	PAEL	AELP	PAEL	PAEL	AELP	LP	Pea & Bean Family	Dry Fields
Coral Hair-streak	E	E	EL	LPA	PAE	AE	E	E	Wild Cherry	Open Fields
Banded Hair-streak	L	L	L	LPA	AE	AE	EL	L	Hickory	Wood Roads & Woods
American Copper	P	PA	AEL	AELP	PAEL	AELP	PAEL	AELP	Sorrel	Fields Roads, Meadows
Tailed Blue	L	PA	AEL	AELP	LPAE	AELP	AEL	L	Round-headed Bush-clover	Open Fields, Meadows
Common Blue	P	AE	AEL	AELP	AELP	AEL	AELP	LP	Maple-leaved Arrow-wood	Open Woods
Silver-spotted Skipper	P	P	AEL	LPAE	PAEL	AEL	ALP	LP	Locust	Open Fields near Locust Trees
Sooty-wing	L	LP	PAEL	AELP	LPAE	PAEL	AEL	L	Pigweed, Amaranth	Waste Places, Roads
Least Skipper	P?	P	PA	AEL	PAEL	LPAE	AEL	P?	Grasses	Grassy Places, Fields & Meadows
Tawny-edged Skipper	P	P	PA	AEL	AELP	LPAE	AEL	LP	Grasses	Grassy Places, Fields & Meadows
Yellow-spotted Skipper	LP	LP	PA	PAE	AEL	LPAE	AEL	LP	Grasses	Grassy Places, Fields & Meadows
Volcanic Skipper	L	L(P?)	(LP?)	PAE	AEL	AEL	L	L	Grasses	Grassy Places, Fields & Meadows
Mormon Skipper	LP	LP	PA	PAE	AEL	L	LP	LP	Grasses	Grassy Places, Edges of Woods, Meadows
Little Glass-wing	L	L	LP	PAE	AEL	AEL	L	L	Grasses	Grassy Places, Fields, Meadows

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THE AMERICAN MUSEUM OF NATURAL HISTORY

HOW TO COLLECT AND PRESERVE INSECTS

By FRANK E. LUTZ

GUIDE LEAFLET SERIES, No. 39
EIGHTH PRINTING, DECEMBER, 1936

NOTE

These leaflets are intended to furnish accurate information in regard to the preparation of specimens of various kinds for Museum purposes.

The following have been issued and may be purchased at the Museum Book Shop or from the Librarian; others are in course of preparation.

The Capture and Preservation of Small Mammals for Study
By H. E. Anthony. Price 15 cents

The Preparation of Birds for Study
By James P. Chapin. Price 15 cents

How to Collect and Preserve Insects
By Frank E. Lutz. Price 15 cents

The Preparation of Rough Skeletons
By Frederic A. Lucas. Price 10 cents

HOW TO COLLECT AND PRESERVE INSECTS

By FRANK E. LUTZ
Curator of Entomology

American Museum of Natural History
Guide Leaflet No. 39
Eighth Printing
New York, December, 1936

This leaflet was prepared by Dr. F. E. Lutz in response to numerous requests for information as to how to collect and preserve insects and is now issued as one of a series intended to furnish accurate information in regard to the preparation of specimens of various kinds for museum purposes. To some extent it complements the leaflet "Our Common Butterflies," as that tells what the butterflies are, and this how to catch and take care of them and other insects.

There is a widespread but erroneous idea that collecting insects yields a satisfactory financial return. The amateur will profit greatly in health, pleasure and instruction, but should not approach nature with money in his eye.

American Museum of Natural History
Central Park West at Seventy-ninth Street
New York, N. Y.

HOW TO COLLECT AND PRESERVE INSECTS

By Frank E. Lutz

WHAT ARE INSECTS?

"Insects are hexapodous tracheate arthropods," which doesn't help much unless it be translated, for the man who can translate it does not need to be told. On the part of laymen, however, and *this pamphlet is intended for laymen,* there is a good deal of haziness as to what are insects and what are not. Arthropods are creatures having jointed appendages but no internal skeleton. The group includes crabs, spiders and centipedes as well as insects. "Tracheate" refers to the structure of the breathing apparatus, but need not concern us here, for "hexapodous" settles the whole matter if one does not object to exceptions. An arthropod with no more than six legs is fairly certain to be an insect. The exceptions to this are minute immature forms not likely to be noticed by the reader. However, a young insect is an insect as truly as is a full-grown one, and while some young insects (flies, for example) have no legs, others (young butterflies, for example) have more than six "legs." Perhaps if we call these exceptions maggots and caterpillars, enough will have been said. No mention has been made of wings, for two reasons: very many insects never have wings, and no insect has wings or even signs of wings when very young. It may be said here that when an insect does have fully developed wings it is full-grown. A small winged fly never grows up to be a larger fly, as many suppose. Most insects have an outwardly quiet stage, called the pupal, between the crawling larval and the flying adult ones, but many other insects remain active, merely gaining more and more fully developed wings at each molt. Compare in this respect the butterflies and the grasshoppers.

WHEN AND WHERE TO FIND INSECTS

An entomologist is frequently amused at being asked by well-meaning friends if he found anything when he went out. Insect hunting is a sport in which there are no blanks if you know the game. Frequently the most unpromising times and places are the best, for others have been discouraged by the outlook and you get what they have missed. We can never truly say that we know an insect's haunts until we can tell where to look for it every hour of every day in the year. If you wish to confuse an entomological friend, find out where an insect sleeps, then ask him if he knows, or request him as a favor to get you some common insects in the winter. Most insects are great hiders and should be looked for under bark; in rotten wood; under stones, dead leaves, etc.; among the roots of plants; in their stems and flowers—in short, everywhere at all times.

COLLECTING APPARATUS AND HOW TO USE IT

The great essentials for insect collecting were given each of us at birth and need only be improved by use—an inquiring mind, eyes and fingers. Only a very few insects sting to such an extent that collecting with unaided fingers is uncomfortable, and even the swiftest flies can be caught by hand when they are young or asleep. However, certain tools are handy. They can either be made at home or purchased rather cheaply from dealers.

Mention of insect collecting immediately suggests a net. For the capture of adult butterflies, moths and other delicate flying creatures this should be of the lightest possible material. Fine Brussels net or bobbinet is used for the larger sizes (one or two feet in diameter) and silk veiling for the pocket sizes. The depth of this net should be at least twice the diameter of its rim, so that when an insect is caught a twist will fold

the bag against the rim and leave the insect imprisoned in the lower end of the bag. Some collectors prefer green nets, believing that insects do not see them so well; and others black, because one can see through black netting readily; but most collectors use white. The beginner is apt to choose too long a handle and can then take only long slow strokes even if he does not get all mixed up with the vegetation and his fellow collectors. Three feet is long enough to handle, especially if one handles well the two feet which are covered with shoes.

The sweeping net should be made of stout white muslin or light duck on a strong rim well fastened to a handle of such a length that the user can just touch the ground with the rim of the net without stooping. The diameter of the net depends somewhat on the strength of the user and its depth may be from 1½ to 2 times its diameter. It is used to sweep blindly through the grass, bunches of flowers, light bushes, etc., in a fairly certain expectation of getting something. Much of the material will be damaged by the rough handling, but it is the quickest way to get large numbers of specimens, and the only way to get certain things quickly. The tendency seems to be to make the handle of the sweep net too short, some on the market being only six inches long. These do not tire the arm so much as nets with longer handles, but you either miss the insects living near the ground or you get a very tired back. One useful trick in sweeping is to have a small cushion (about 2 by 1½ inches) of cotton covered with cheesecloth or muslin and a bottle of chloroform, ether, or carbon tetrachloride ("Carbona" or "Pyrene"). After sweeping for a few minutes moisten the cushion with the anesthetic, drop it into the net and quickly twist up the bag so that the fumes are confined. In a short time even the liveliest grasshopper will be asleep and can be picked out and either saved or rejected. If rejected they will all shortly revive and walk, hop or fly away. The cushion is not strictly necessary as the anesthetic may be

put directly on the net after the insects are folded in the bottom.

The third net of the complete outfit is the water net. The bag should be of some strong material through which water will run readily. The rim should be strong and may be either circular in outline or flattened at the side opposite the handle. The advantage of the flattening is that the bottom of ponds can be skimmed, but the circular rim does fairly well, as the stirring of the water stirs up even the bottom insects and they are caught in the return swish of the net. A great deal of mud and weeds will also be caught, but devices to prevent this, such as covering the mouth of the net with a coarse wire screen, do not work well in collecting insects. After clearing the net of mud as much as possible by washing it through the net, dump the rest on the bank, preferably in the sun. Some insects will probably be seen at once, others will appear as the mass dries out. After you think you have found everything, wait a while and look out for very small beetles. Many collectors miss them.

Many or most of the nets that are for sale have folding rims and jointed handles. Opinion differs as to the best. When, as is often the case, lightness and ease of transportation are objects, it is well to have but one handle and frame with interchangeable bags. The landing net used by fishermen in which the frame consists of two pieces of flexible steel that lie close together when not in use is excellent. The two-jointed handle is better than the three-jointed one, as one of the joints of the former is just right except for high flying or deep diving quarry. In these cases add the second.

A sieve is handy for getting the small insects hiding under accumulations of dead leaves, in moss, trash, etc. Two sieves with meshes of different size are handier. A good plan is to have a strong bag about a foot and a half square by two feet deep. About nine inches from the top sew strips across the corners so that a piece of half-inch mesh wire screen can rest

on them. Sift through this until there is quite a bit of fine material in the bottom of the bag and then retire to a comfortable place protected from the wind and spread a small sheet of white muslin or canvas. Now resift, using a mesh about four or five to an inch. The flat-bottomed sieves six or eight inches in diameter which are used for making French fried potatoes and the new wire pie-pans are excellent. Sift a very thin layer on to the white cloth and examine carefully the coarse stuff for relatively large things before it is thrown away. Be patient with the small stuff. Insects have a habit of "playing possum" and have plenty of patience themselves. They do not seem to like tobacco smoke. If you do, blow some on the litter. It will hasten matters—at least, smokers think so.

This is a good place to mention collecting forceps as they are almost necessary in picking up very small insects as well as insects concerning whose ability or inclination to sting there may be some suspicion. The best forceps for handling very delicate insects do not seem to be on the market. They are made of strips of German silver and have small but rounded points. However, the small steel ones which are on the market do very well. Steel forceps about a foot long are handy for picking caddice cases, etc., out of water, but they are of little use in general work. Dealers also carry forceps having gauge-covered frames at the tips. They are meant for holding stinging insects while they are being examined, but they also are of very little use to the general collector.

A strong knife for cutting off galls, stripping bark, splitting infested branches, etc., is essential. A trowel is useful in following insect burrows or digging for root borers. The entrenching tool used in the army is a handy, all-round trowel, hatchet and large knife combined.

There are two chief methods of night collecting in general use: sugaring and at light. Another, while not so productive of specimens, is more interesting. It consists in simply

prowling around with an acetylene bicycle lamp or a portable electric light examining the centers of flowers, the underside of leaves, tree trunks, etc., to find out what the nocturnal insects are doing, and also where and how the day-flying insects are passing the night.

There are about as many recipes for making the sugar mixture as there are for "mother's biscuits." Baking molasses usually forms the basis. Some additions are any combination or all of stale beer, rum, when obtainable, asa-fœtida and brown sugar. The mixture should spread easily but not run badly. It is to be applied before dusk on tree trunks, fence rails and the like. Starting from some comfortable resting place as a base, lay out a circuitous route, "sugaring" something every few feet and end at the resting place. After dark, if luck be good, the sugared strips will be full of moths, eagerly sipping the sweets. Several wide-mouthed cyanide killing bottles (see page 13) will be useful, but a net will be practically useless. It is well to have a little ether in each bottle, and do not put a moth in a bottle until its predecessors have stopped fluttering. Only experience will teach how to catch these moths with a bottle. Some fly upward when disturbed and some fly straight out or sideways, but the majority drop a few inches before flying, so when in doubt hold the bottle slightly below the prospective captive.

Light attracts many sorts of insects besides moths. Street and porch lights are fruitful hunting grounds. A lamp by an open window makes the room it is in a splendid trap, or a smaller one can be fixed up and put "in the field." Figure 1 shows the principle. The details vary to suit collectors' whims. It is not difficult to make the box collapsible so that it can easily be transported. An ordinary barn lantern set in the center of a white sheet or a "bull's-eye" throwing a light against a sheet hung over a fence or between trees does very well. In the latter cases a net will be desirable but not

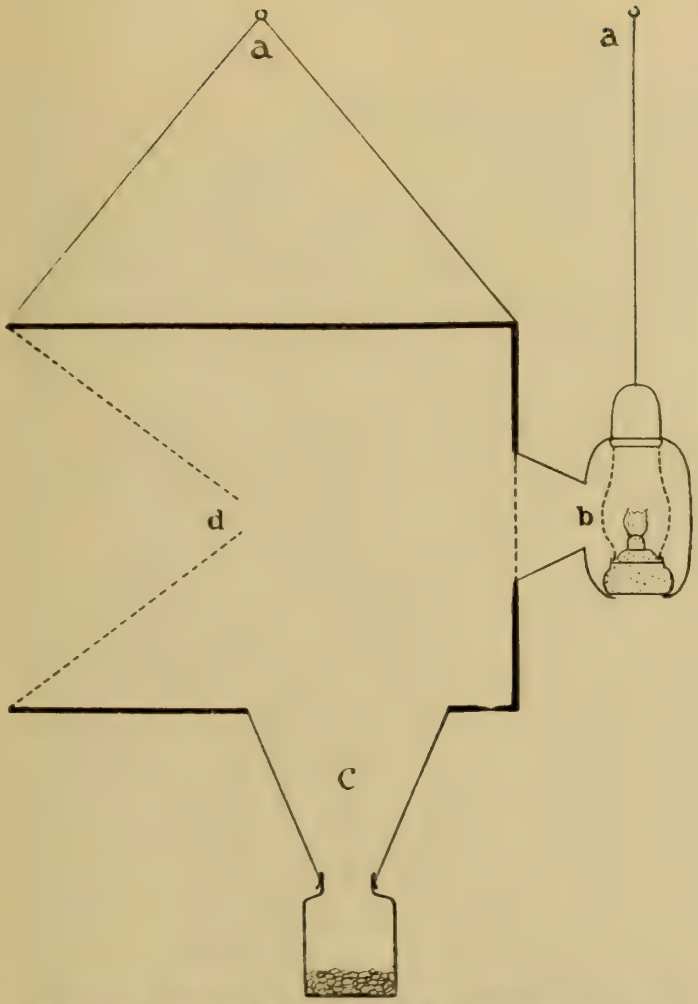

Figure 1. **SECTION OF A TRAP FOR INSECTS** which are attracted by light. **a,** Supporting strings; **b,** Lamp shut off from the trap by a glass plate or netting; **c,** Canvas bag with cyanide bottle; **d,** Glass plates or netting set at an angle. The space between the inner edges of **d** should be about one inch wide.

easy to use. I have used, with great success, a white cheesecloth tent with a white muslin groundcloth. The best tent was A-shaped, open at each end except for inwardly projecting flies, and about 9 ft. x 6 ft. x 6 ft. high. One or two lanterns, placed inside, made it a good trap, while the outside served as illuminated sheets. Both light and sugar work best where there is a variety of vegetation as where woodland passes into swamp or where there is an abundance of second growth.

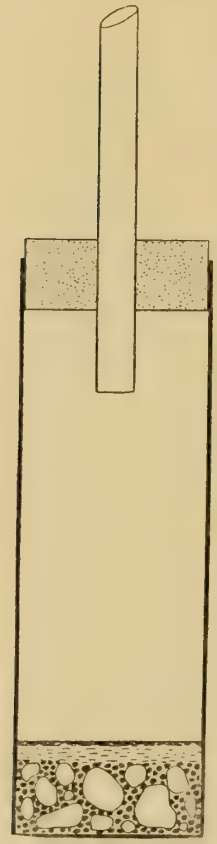

Fig. 2. **COLLECTING TUBE** fitted with a quill for getting insects out of an umbrella.

Many other sorts of traps have been devised. Olive bottles and fruit jars buried up to the neck in the ground and baited with molasses, meat, etc., are simple and effective. The insects caught in this way may be washed off in alcohol and will be nearly as good as new. Boards daubed on the under side with molasses or covering meat are not bad. Girdled branches and cut limbs hung up attract wood-boring insects which can be then collected by beating them into an upturned umbrella by sharply rapping the limbs with a stout stick. In fact an umbrella is a very useful piece of apparatus. Branches, both living and dead, are full of insects. The inverted umbrella catches what are knocked off but does not hold them for long. The collector must act quickly. Some collectors put a quill in the cork of a collecting tube as shown in Fig. 2. If the outer end of the quill be put over the insect the captive will crawl up through the quill and into the bottle, from which exit is difficult.

If the umbrella be white, or at least lined with white, the insects can be more easily seen but so can the collector—not by the insects particularly, but by inquisitive humans,—and the non-committal black does very well.

Fig. 3. **A BREEDING CAGE.** The flower pot holds earth which contains a growing plant or a bottle with fresh twigs. The lantern globe with a netting cover confines the insects.

Beating will knock down many larvæ. Directions for preserving them are given on page 21. Some, at least, should be reared and here ingenuity is of more value than volumes of instructions. The beginner will doubtless be inclined to give his charges more light and air than necessary. Pasteboard shoe boxes are excellent for large caterpillars. Tin boxes keep the food longer and are easily cleaned but must be watched carefully or the food will mold. If the food-plant can be potted, a good contrivance is to slip a lantern globe over it, sinking the bottom far enough in the ground to prevent the escape of larvæ in that direction and covering the top with cheesecloth.

Even if the plant cannot be grown, twigs can be kept fresh for some time by keeping their cut ends in a small bottle of water sunk in the ground and used inside a lantern globe (see Fig. 3). The twigs will be held in place and the larvæ prevented from drowning if cotton be loosely stuffed in the neck of the bottle around the twigs. It is well to throw a thin layer of dirt over the cotton so that fallen larvæ can easily get back to their food. A useful device for certain larvæ (not leaf eaters) is shown in Fig. 4. It is made of plaster of Paris. The water at one end keeps the block moist. It is useful chiefly for ground-inhabiting larvæ or

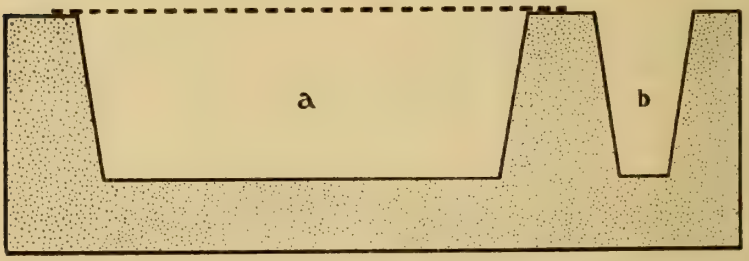

Figure 4. **SECTION OF PLASTER BREEDING BOX. a,** Space for insects: **b,** Space for water. The broken line represents a glass plate.

for galls. However, for the latter fruit jars with moist sand or a moist sponge in the bottom do just as well or better. Do not forget the larvæ living in hollow stems, dead wood and under bark.

KILLING

Up to this point but little mention has been made of killing insects and that was not really necessary. Insects can be studied alive with great pleasure and profit. However, there are so many kinds (about 15,000 in the vicinity of New York City, for example) and the differences between species are often so minute that it is well to kill and preserve samples at least. Fortunately this can be done with less trouble and less

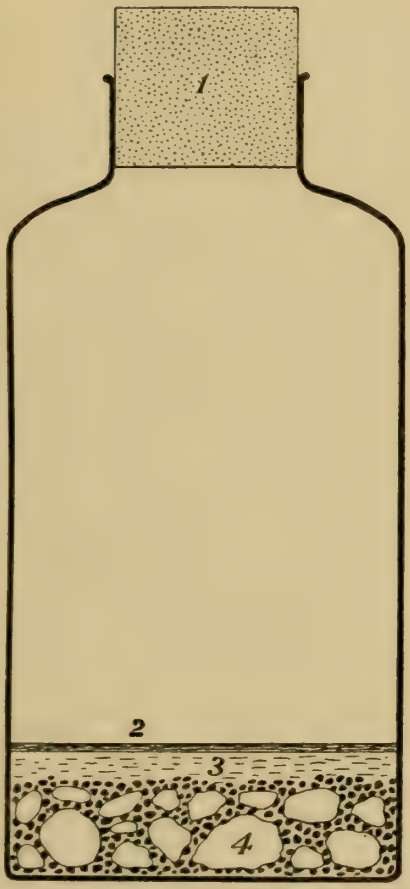

Figure 5. **CYANIDE KILLING BOTTLE.** 1, Cork; 2, Blotting paper; 3, Plaster of Paris; 4, Pieces of cyanide in sawdust.

injury to the balance of Nature than is the case with most animals or even plants. Furthermore, the collection can be made very attractive and instructive without taking up much space.

The best all-round killing agent for adult insects is cyanide of potassium. It should be broken into pieces varying in size from that of a small pea to that of a hickory nut, according to the size of the bottle to be used. Olive bottles make good medium-sized bottles, while fruit jars are better for large moths and butterflies. Tubes even as small as ½ inch in diameter by about 2 inches long are not too small for some things. Avoid bottles with strongly constricted necks. Avoid also bottles made of thin glass. There are many ways of keeping the cyanide in position and the bottle in good condition. The most general way is to pour a thin layer of plaster of Paris over a layer (from ¼–¾ inch deep) of cyanide. However, since such a bottle will quickly get too moist from the specimens and decomposition of the cyanide, some further device is almost always used. The pieces of cyanide may be wrapped in soft absorbent paper or imbedded in dry sawdust before the plaster is poured on. Another way is to imbed it in dry plaster before pouring on the wet. A piece of blotting paper should be fitted tightly over the plaster after it has "set." See Fig. 5. Some do not use plaster but imbed the cyanide in cotton and cover this with a piece of blotting paper or a thin porous cork. A dangerous but otherwise fairly satisfactory method is to imbed a piece of cyanide on the inside surface of the cork and have none in the bottle itself. This bottle will be dry but not strong and as the cork will in time become saturated with poison it will be very dangerous. It is always well to have a few narrow strips of loose absorbent paper in the bottle. They prevent injury to the insects by shaking and will keep the bottle dry, as they can be frequently changed. As ordinarily made, a bottle should be allowed to ripen for several days before using. If

wanted at once, put a few drops of vinegar or a pinch of boracic acid powder with the cyanide. Collectors of delicate moths and butterflies frequently put a few drops of ether or chloroform in their cyanide bottles before starting out. This is to quiet the insects at once, for the cyanide sometimes kills slowly. Experience will teach the collector that some insects die very slowly and revive after apparent death. On the other hand, ether and chloroform make insects brittle and too long an exposure to cyanide fumes changes the color of some insects. "Carbona," or carbon tetrachloride, is a good killing agent and safe for children to use. A few drops on cotton in a bottle are sufficient.

Practically all beetles and dragon flies, together with dull-colored hairless insects of other orders, can be killed in alcohol and kept there indefinitely—50% is strong enough for killing and 70% for preserving. Higher grades make them brittle. No fly, bee, butterfly, moth or any green insect other than those previously mentioned should be put in alcohol. In an emergency, kerosene, gasoline or benzine put on the thorax will kill and give satisfactory specimens. The thorax is the part of the body which bears the wings and legs. Insects breathe through holes in it and in the abdomen, not through the head. Pounded laurel leaves and peach pits make a weak killing agent, and butterflies and moths may be killed by carefully but firmly pinching the thorax between the thumb and finger, one on each side. In fact, many collectors of these insects pinch their captures before taking them out of the net. This stops their injuring themselves by thrashing about.

MOUNTING

We come now to the methods of mounting and preserving. The stock method is pinning. The almost universally adopted pin is 1½ inches long and has a very small head. It varies in thickness from extremely slender to as thick as an ordinary pin. The useful sizes are from No. 0 to No. 3. They are

either plain "white" or enameled black. Much is to be said for each with the voting probably in favor of black. At any rate, they should snap back when bent a reasonable amount. A pin that bends easily and stays bent produces profanity. Beetles are usually pinned through the right wing cover. All other insects, when pinned, are pinned through the thorax. In the case of flies it is well to pin a trifle to the right of the middle line as the bristles on the back are important in taxonomy and one side of the body should be perfect. True bugs should be pinned through the triangular portion of the thorax which is between the wings. See Fig. 6.

Figure 6. The black dots show where the pin should be inserted.

Very small insects are usually mounted on the tip of paper triangles, a medium-sized insect pin being stuck through the broad end of the triangle. The triangles are of about as many sizes as there are collectors. A ticket punch can be purchased which has a die suitable for cutting these triangles. However, if they be cut out with scissors or a sharp knife such as a razor, a variety of sizes and shapes suited to different insects can easily be made. The best way is to cut tough, rather stiff paper into strips about three-eighths of an inch wide and then snip off triangles from them by making transverse cuts. It is well to pin a quantity of these triangles in odd moments and keep them on hand. When ready to mount, put a small bit of white shellac dissolved in alcohol or of some good elastic glue on the tip of a triangle and touch

it to the under side of the thorax. Some difficulty will be experienced in keeping the insects straight on the point, especially if the adhesive be too thin. The triangles for ants should be fairly broad at the "point," and the front end of the abdomen as well as the thorax should be supported.

The method just mentioned is almost universally used for small beetles. Small flies and the like are frequently mounted on "minuten nadeln." These are short, very delicate, headless pins. Their use is illustrated in Fig. 7. Bits of pith, cork or firm blotting paper (used edgewise) serve to connect the two pins. In the illustration the "nadel" is shown stuck through the insect and then into the support. A somewhat better plan is to arrange a number in advance by sticking the "nadel" through the support from below, leaving the point sticking up; then mounting can be done rapidly by piercing the insects from below. It is well, in this case, to stop before the point comes entirely through the back, as then no pin shows and furthermore the characters on the back are not marred. "Minuten nadeln" have the advantage over glue on triangles that the glue does not always hold. On the other hand, the "nadel" cannot be used with many hard-shelled beetles. Elbow pins (Fig. 7) are sometimes used but are not very satisfactory as a rule. The mounts mentioned in this paragraph are usually put on the left side of the pin.

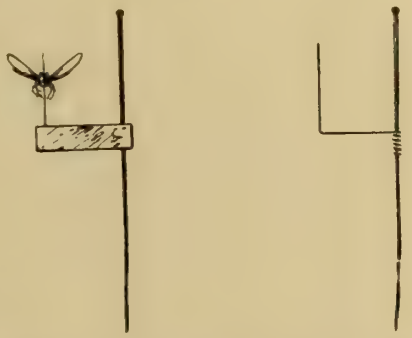

Figure 7. Pins for mounting small soft-bodied insects.

The height of the insects on the pin is important for the final appearance of the collection. A strip of cardboard whose

width is one-quarter to one-third the length of the pin makes a convenient gauge. With one edge held at the head of the pin, push the insect up until it touches the other edge. Or a block of wood containing a hole whose diameter is a trifle larger than that of the pin's head and whose depth is one-

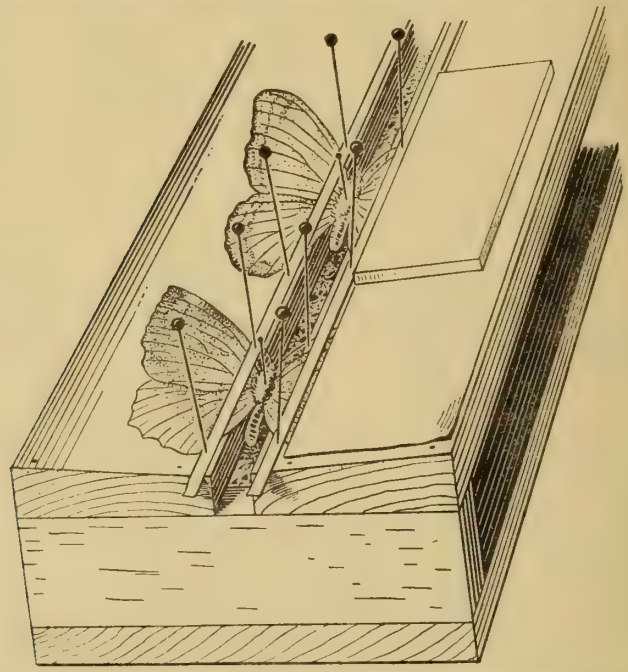

Figure 8. **A COMMON TYPE OF SETTING BOARD** showing different stages in "spreading."

quarter to one-third the length of the pin may be used. Devices for regulating the height by sticking the point of the pin into a gauge are not satisfactory because of the varying thicknesses of the specimens.

Mounting insects in balsam on glass slides will probably not be taken up by the general collector unless he be already

accustomed to making balsam mounts. It is, however, the only satisfactory method of getting extremely small mounts ready for study.

In collections, butterflies and moths usually have all four wings expanded to their utmost and more or less in line with the lateral axis of the creature's body. This makes a nice-looking collection and is the best that can be done with most butterflies. However, many moths have natural rest positions which are not only interesting but economical of space, It is well, therefore, to expand the wings of the left side so that the markings on both the front and hind wings show, but to leave the right wings in the natural rest position. The reason for expanding the left side rather than the right and for putting the triangles, etc. (see above) on the left side is that most people are right-handed. This arrangement makes it easy to use the pinning forceps with the right hand. Pinning forceps are strong forceps with broad roughened ends and are useful in pushing the pins into the cork of the storage boxes (see page 24). For the same reason when the wings of grasshoppers, wasps, etc., are spread it should always be the left wing.

The most common form of spreading board is illustrated in Fig. 8. The sides are made of soft wood. In the bottom of the central channel is a piece of soft cork. After pinning the insect, push the pin into this central cork until the back of the insect is nearly flush with the board. Then draw the wings to the desired position by means of forceps or a fine needle caught in the strong front margin of the wings. Never use the fingers on moths and butterflies as they will rub off the scales which cover and give color to the wings. The wings may be held in position by means of fine pins or bits of heavy glass or strips of tracing cloth, held in place by pins placed outside of the wings. A combination of the last two methods, glass on paper, is best. It is well to have a number of boards with grooves of different widths for use with different-sized insects.

Figure 9 shows a setting board devised for spreading caddice flies and other insects when it is desired to have the legs spread as well. The holes running down the center are just large enough to accommodate that part of the pin which is above the insect. The wings are spread as before except

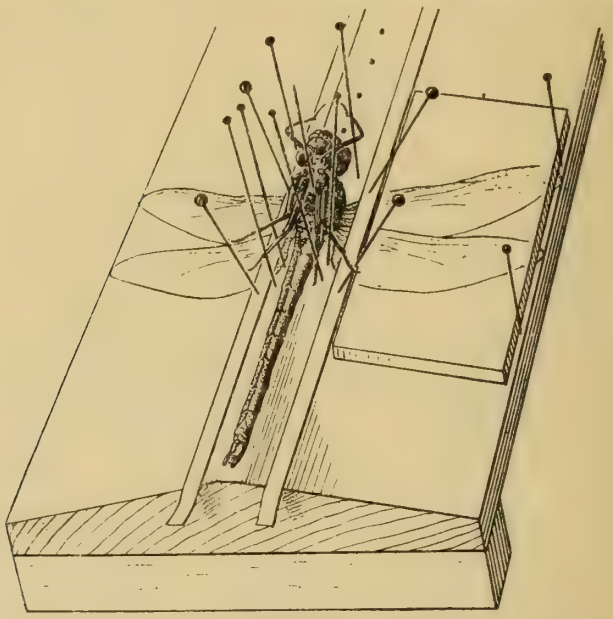

Figure 9. **SETTING BOARD** for use when it is desired to spread the legs.

that now the under side is visible to the worker and the legs are accessible.

Flies (insects which have just one pair of wings), beetles (insects which have hard front wings) and bugs (insects which have the front part of the front wings leathery) are rarely spread although they may be. The wings on at least one side of wasps should not be spread, as the way they fold them is of taxonomic value.

Should insects get dry and stiff before they are spread they must be relaxed. This is done by putting them in a covered jar or tin box containing water or moist blotting paper. A few drops of carbolic acid added to the water will prevent mold. Twenty-four hours will usually be sufficient to relax even the driest, but more time may sometimes be necessary. If the insect has neither scales nor hairs, it can be quickly relaxed by immersing it in warm water.

It will be noticed that both the setting boards illustrated here give the wings a slight upward tilt. If they keep this position it will not be objectionable, but they are not likely to do so, since the weight of the wings will probably drop them to the horizontal at least. Large insects dry more slowly than small ones and it will probably be necessary to allow them to remain on the boards for about two weeks. They should certainly remain until thoroughly dried. No further preservation is then necessary, as a rule, for the fairly hard-bodied adult insects. Some tropical grasshoppers have large abdomens full of fat and decomposing food. These should first be opened by an incision along the belly, the viscera taken out, and the abdomen stuffed with cotton. Broken specimens may be repaired with shellac or thin glue.

Caterpillars may be prepared in the following way. Make a circular incision at the hind end, cutting the intestine loose from the outer body wall. Then, laying the caterpillar on a piece of clean blotting paper, squeeze the viscera through this opening by gently rolling the caterpillar with a lead pencil, beginning near the hind end and gradually working toward the front. After the viscera have been gotten rid of, for the most part, insert a straw and fasten the first segment of the larva to the end of the straw by means of a fine needle. Draw the hind segment up the straw until the larva is natural length and fasten it in the same manner. Then inflate the larva by gently blowing through the straw. Since the front end of the straw may get plugged up, it is well to make a small hole in

Figure 10. A field card such as is used at the American Museum.

the side of the straw before it is inserted. This hole had best come about midway between the larva's head and tail. Since inflation must be kept up until the larva's skin is dried, gentle heat is ordinarily used. A tin can with holes punched in it for ventilation and heated by an alcohol lamp makes a good oven or one made for the purpose can be purchased. Dealers also sell bellows, tubing, clips, etc., to make the work of inflating easier. However inflated, green larvae are apt to lose their color, for it is chlorophyll, which fades rapidly. Slow-drying paints relax the skin and distort it. Therefore, if painting is done, the pigments should be mixed with benzine or the like.

FIELD NOTES AND LABELS

It is only by the merest chance that the beginners get a new or even a rare species on ground that has been worked over by experienced collectors, but even the primary class in entomology may add to our store of knowledge if it keeps field notes well. Date of capture and locality are considered of prime importance. They should always be known and kept with every specimen, but the distribution and time of appearance of our common species are known. It is of their habits that we are ignorant. What do they feed on? Under what conditions are they to be found when young and when old, day and night, winter and summer? What do they do and how do they do it?

A sample field card is shown in Fig. 10. The "Remarks" are really the important part. In using this card the lower right-hand number is torn off (after filling out the card *in the field*) and kept with the specimens to which the card refers until they are individually labeled. This is the card used in the American Museum. The stub is kept by the collector and the card is filed at the Museum. Such a refinement of system is not necessary in most cases, but some system is imperative if your collection is to be worth while.

Figure 11.

The pin label should be small but legible. Certain firms make a business of printing these labels from small type, or the collector can make up a sheet by means of an ordinary typewriter (black ink is best) and have a block made from this greatly reduced in size. From this block any number of impressions can be made. Any printer will attend to the whole business. Figure 11 shows sample strips. If dates are not printed they should be filled in before cutting the labels apart. Field numbers can be written on the back of these labels or put on a separate label. The collector's name can also be put on a separate label. Similar labels should be the same height on the pin throughout the collection. This is easily accomplished by sticking the pin first through the label then into a hole of given depth or cork of a given thickness, thus pushing the labels up to a uniform height.

STORAGE BOXES AND CARE OF COLLECTION

Since certain members of a family of beetles (Dermestidæ) are given to eating dried insects, the storage boxes should have tight-fitting lids. Except for that, almost anything will do. Cigar boxes are not bad if carefully watched, but better boxes can be purchased at reasonable prices from dealers. Glass topped drawers are nice but not necessary. Whatever sort of box is used, the bottom, inside, should be covered with something which is soft enough to allow a pin to enter easily but which will hold the pin when it is once in. The compressed cork of the dealers is best. Sliced cornstalk is used by some beginners but two layers of corrugated paper, such as bottles are packed in, is better than corn pith. The layers should be placed so that the corrugations run at right angles to each other.

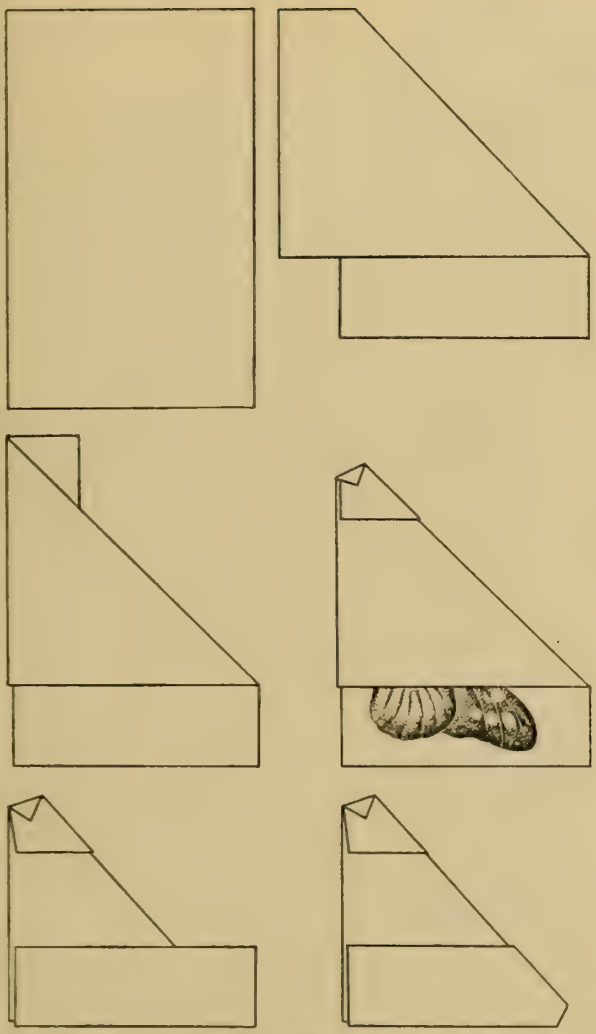

Figure 12. **METHOD OF PACKING A BUTTERFLY.** The paper used in making the envelope should be stiff enough to protect the wings.

In spite of precaution Dermestids may get in, although camphor balls or flaked naphthalene will help to keep them out. If camphor balls are used, first heat the head of an ordinary pin and while hot push the head into the ball. When cool, it will be solid and the ball can be pinned into the box. If Dermestids do get in they may be killed by pouring into the box about a teaspoonful of carbon bisulphide and closing the lid down tightly. Remember that the bisulphide is very inflammable.

PACKING INSECTS IN THE FIELD

It frequently happens that the collector cannot attend to his catch at once, or possibly for months. Of course those things which are collected in alcohol may remain there. Butterflies and the like should be put into triangular envelopes. The manner of making these is shown in Fig. 12. Never put more than one specimen in an envelope. Other insects can be packed between layers of cotton and cheesecloth, with naphthalene flakes put in to keep out ants, etc., or they can be put in sawdust. In the latter case it is well to sprinkle carbolic acid on the sawdust to prevent mold. An excellent method of packing insects (except butterflies and moths) which are to be dried, is to make tubes of unglazed paper around a lead pencil, first writing the data on that part of the paper which comes outside. One end is closed by folding in the paper there, and then the tube is nearly filled with freshly killed insects. Finally the other end is closed by folding in the paper. These tubes and the triangular envelopes can be packed in a cigar box, and, if sprinkled with naphthalene to keep out ants and Dermestids, will keep indefinitely. Never pack moist insects in a tin box and never close even a wooden box tightly if there are many moist insects in it. Mold will result if you do.

IDENTIFICATION

Several popular leaflets for the identification of our more common or popular insects (e.g., butterflies) have been published by the Museum and may be purchased for a nominal sum. Others are being prepared and the study collections at the Museum are open to students upon application. *The Butterfly Book* and *The Moth Book,* both by Holland, are recommended for work in these groups. Blatchley's *Coleoptera of Indiana* is useful for students of beetles, except snout-beetles and their relatives, even along the Atlantic coast. For those beetles omitted in Blatchley, see Blatchley and Leng's book on *The Rhyncophora of the Eastern States;* both these books, however, are for professionals and advanced amateurs, rather than for beginners. Comstock's *Manual for the Study of Insects* and Kellogg's *American Insects* give good surveys of American entomology, especially as regards anatomy and the broader phases of the subject. The author's *Field Book of Insects* (Putnam's) is intended to answer "common questions about insects," and to enable the beginner to identify about 1,000 of the more frequently seen or more interesting species of Eastern North America. Volumes V and VI of the *Cambridge Natural History* and Imms' *General Textbook of Entomology* are probably the best English books on insects of the world.

FINALLY

Do not forget that information about the insects is usually of as much value as the specimens—or more.

FOR THE PEOPLE

FOR EDUCATION

FOR SCIENCE

GENERAL GUIDE TO THE EXHIBITION HA

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INDIANS

#41

OF MANHATTAN ISLAND AND VICINITY

by

Alanson Skinner

THE INDIANS
of Manhattan Island and Vicinity

By ALANSON SKINNER

SIXTH EDITION

SCIENCE GUIDE No. 41

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A MAHIKAN INDIAN CHIEF FROM THE HUDSON RIVER BELOW ALBANY

Note his warclub, the shape of which is common in his region, the thunderbirds painted or tattooed on his face, and his belt embroidered with dyed deer's hair. His totem, the Tortoise, is at his feet. This man and the three Mohawk Chiefs shown following formed a party which visited England in 1709.

From an engraving in the possession of the New York Historical Society.

THE INDIANS OF MANHATTAN ISLAND AND VICINITY

By Alanson Skinner

INTRODUCTION

THERE is no subject which makes a more forceful appeal to the student, the historian, or even the general reader, than that of the native inhabitants of what is now Greater New York; yet there is no subject upon which it is more difficult to obtain information, for our Colonial ancestors have left us but few accounts of their observations, and these are in tomes that are rare and difficult of access.

The aborigines themselves have so nearly passed into oblivion, that no help can be obtained from their scattered and degenerate remnants in exile in the west, so that we must turn to two sources for our knowledge: the writings of the first white settlers, already mentioned, and the archaeological remains, the imperishable objects of stone, clay, bone and antler, which the vanished red men have left behind them on their ancient dwelling places.

The writings of the Colonists tell us that in appearance the Manhattan and their neighbors were tall and well-built, with black hair and eyes and not unpleasing faces. Their disposition is noted as mild, except when aroused, when they are said to have been very greedy of vengeance.

The men shaved their heads, or rather burned off their hair with hot stones, leaving often a standing roach of stiff black hair two or three inches high and as many broad, running from the forehead to the nape of the neck, and the lock which hung from the crown was generally allowed to grow much longer. This was the famous *scalplock*, which the warrior cultivated in defiance of the enemy, who might take it if he could. Sometimes they wore a roach of red dyed deer hair, exactly similar to those worn by the Sauk, Fox, Menomini, and other tribes of the Central West. Our Indians *did not* wear the feather war-bonnet so characteristic of the Sioux and other tribes of the Great Plains, and which is now always placed upon the Indians in the conventional drawings picturing the sale of Manhattan Island.

A MOHAWK CHIEF FROM THE MOHAWK VALLEY

Observe his tattooing and his belt embroidered with dyed deer's hair. His totem, the Bear, is shown at his side.

From an engraving in the possession of the New York Historical Society.

The Manhattan and their neighbors, unlike the Indians west and north of them, wore no shirts nor coats. Instead, they covered the upper parts of their bodies with robes made of dressed deerskin, or wolf, wildcat, or bear fur, or of the shimmering feathers of the wild turkey, neatly attached to a netted fabric. So closely and carefully were these feathers applied that they are said to have shed the rain.

The men also wore loin cloths or breechclouts of dressed leather, and leggings and moccasins of the same material. The moccasins of all the Indian tribes east of the Mississippi had one point in common, they were soft-soled, but west of the Mississippi region the tribes of the prairies used hard flat soles of rawhide for their shoes.

In addition to this costume, the warriors wore necklaces of dyed deer hair, of native copper or shell beads, or of wampum; and often they hung over their chests pendants of stone or gorgets, such as are still to be found occasionally upon the sites of their old camps. They also painted their faces with various pigments, especially red and black, which they obtained from limonite and graphite fragments. To this day one may find in the débris of an abandoned Indian village bits of these paint stones showing the striated markings of the stone scrapers with which the color was removed for use. The Manhattan, being a part of the Delaware tribe, an important group of the Algonkin stock, probably followed the ancient Delaware custom of tattooing their bodies, with designs representing their dreams and warlike exploits.

Old paintings of the Delaware show us that they wore their knives, and even their tobacco pipes and pouches, suspended from their necks. The reason for wearing their knives in this position, old Indians of some of the central western tribes declare, was so that they could be more readily seized at a moment's notice. Besides his deerskin tobacco pouch with its dyed hair and porcupine quill embroidery and leather fringe, each warrior carried a warclub, carved of wood, with a ball-shaped head set at right angles from the handle, and a six-foot bow and a quiver containing flint, bone, or antler-tipped arrows.

The women were differently clothed from the men. They often wore their hair in a braid, over which they drew a "square cap" ornamented with wampum. Presumably this hair dress was similar to that used by the Winnebago and Sauk and Fox women of the middle west, examples of which may be found in the cases in the Eastern Woodland Hall under the various tribal designations.

The women, like the men, were naked to the waist, save for the robe, which was shifted from side to side, according to whence the coldest wind

A MOHAWK CHIEF FROM THE MOHAWK VALLEY

His totem was the Wolf, which is shown beside him.
From an engraving in the possession of the New York Historical Society.

blew. They wore, however, knee leggings instead of the hip length style of the warriors, and wrapped about their waists a single square piece of fringed leather, which was open at one side. Sometimes these skirts were not made of leather, but instead were of cloth woven from Indian hemp, such as was also used to make bags. The women covered their gala costumes with wampum beads, and quill or hair embroidery, so that some of the old chronicles declare that a dress of this sort was often worth "above 300 guilders." Of course the women, like the men, protected their feet with dainty soft-soled moccasins.

The houses or wigwams of the Manhattan and their neighbors were never the conical shaped, leather-covered, painted tipis so often shown in illustrations. Lodges of that type were found only in the Great Plains area, and northward up the Mackenzie River and thence eastward about Hudson Bay and Labrador. The Manhattan lodges were of bark, and they and the other local tribes commonly built either square or semi-globular houses of poles arched over and set in the ground, covered with bark, mats made of rushes, with cornhusks, or sedge grass. Such houses looked very much like wooden bowls turned upside down. In the center of each wigwam a hole was dug in the earthen floor to hold the fire so that the sparks might not fly up and ignite the dry walls of the lodge.

In such fire holes, marking the sites of abandoned Indian houses, archaeologists may still find fire-cracked stones, wood ashes, the split bones of deer and other animals broken open to extract the marrow, oyster shells, fragments of earthen kettles, stone and bone implements, and all the discarded débris of the household utensils which were thrown away by their departed owners. Sometimes in such a place whole articles are found, hidden there perhaps during a sudden attack and never recovered by the owner. There too, in winter, when the frozen ground outside made digging impossible, the bodies of the dead were sometimes buried in the useful fireplace, and the lodge either destroyed or set up elsewhere. In proof of this skeletons have often been found in these forgotten fireplaces.

The interior furnishing of a round lodge was simple enough. A bench ran all around the inside of the wall, and on this the inhabitants both sat and slept. Poles swung horizontally from the roof supported strings of braided corn, baskets or bags of food, and other paraphernalia. A hole was left in the roof, directly over the hearth, for the smoke to escape.

Another kind of house, and one that was probably used most frequently in the summer, was a square lodge, made of poles and bark, with a pointed or rounded roof in which a long slot was left at the ridge for the escape of

A MOHAWK CHIEF FROM THE MOHAWK VALLEY

Note the wampum belt. His totem, the Wolf, is shown beside him.
From an engraving in the possession of the New York Historical Society.

smoke. Such a house was commonly occupied by a number of related families, and corresponded in many ways with the long tenements of the Iroquois. None of the houses and few of the villages of the local Indians were ever defended by palisades or trenches.

We are told by the old writers, and archaeological investigation confirms them, that the household utensils of the Indians were pottery vessels, nearly always, curiously enough, made with a pointed bottom, so that they had to be propped up with stones when in use, calabashes or gourds for water, spoons of shell and wood, wooden bowls laboriously made by burning and scraping knots or burls of trees, and bone awls and other tools.

The Indians derived their livelihood by farming a little, for they raised corn, beans, pumpkins, squashes, melons, and tobacco; but mostly by fishing, oystering, and clam gathering. They also were good hunters, as the bones of various animals, so common on their old kitchen refuse heaps, abundantly prove. However, from the vast heaps of oyster, clam, mussel, and other marine shells, that may be found scattered about the old Indian camping grounds, it is obvious that the sea furnished most of their food.

They caught fish in seines and gill nets, by harpooning, and by shooting with the bow and arrow; they killed deer and other game with the bow and arrow, often hunting in large companies. This was, with the waging of war, the duty of the men; the women tended the fields and probably built and owned the lodges.

In their fishing, and for traveling by water, our Indians used canoes, sometimes made from heavy elmbark but more often hollowed out of logs. Roger Williams says of the Narragansett and their neighbors:

> Obs.: Mishoon, an Indian Boat, or Canow made of a Pine or Oake, or Chestnut-trees I have seene a Native goe into the woods with his hatchet carrying onely a Basket and Corne with him, and stones to strike fire when he had felled his tree (being a Chestnut) he made him a little House or shed of the bark of it, he puts fire and followes the burning of it with fire, in the midst in many places: his corne he boyles and hath the Brook by him and sometimes angles for a little fish: but so hee continues burning and hewing until he hath within ten or twelve dayes (lying there at his work alone) finished, and (getting hands), launched his boate with which afterward hee ventures out to fish in the Ocean.
>
> * * * * * * *
>
> Obs. Their owne reason hath taught them, to pull off a Coat or two and set it up on a small pole, with which they will saile before a wind ten, or twenty mile, &c.
>
> * * * * * * *

Obs. It is wonderfull to see how they will venture in those Canoes, and how (being oft overset as I have myselfe been with them) they will swim a mile, yea two or more safe to Land: I having been necessitated to passe Waters diverse times: with them, it hath pleased God to make them many times the instruments of my preservation, and when sometimes in great danger I have questioned safety, they have said to me: Feare not, if we be overset I will carry you safe to Land.[1]

The New York Times for July 16, 1906, writes:

Cherry Hill was the centre of an excited crowd all day yesterday when the news got about that some workmen dug up an old Indian canoe in an excavation at the corner of Cherry and Oliver Streets.

Men, women, and boys and girls flocked to the spot and so blocked the streets that the police of the Oak Street Station had to be sent there to keep order.

The lower part of Oliver Street is made ground, for in the old days the waters of the East River used to wash above the Cherry Street line.

Workmen from the New York Edison Company had made an excavation about eight feet deep when they came to what seemed to be a big log near the bottom. They dug around this and disclosed to view what the police and all others who viewed it said was half of an Indian canoe. Then the workmen, who don't take much interest in anything pertaining to the American Indian, promptly got an axe and chopped away until they got out the timber in sight, leaving the other half still buried in the mud.

In doing this they split the canoe into three pieces, and followed by an admiring crowd, it was carried to the corner of Frankfort and Pearl Streets, and deposited on a pile of dirt under the Franklin Square elevated station, where the night watchman could keep his eye on it until today, when the workmen expect to get the other half and piece the canoe together.

It is supposed that the canoe was lying in the mud a hundred years ago or more, when the river front was filled in to make more land.

The part saved is about 7 feet long and 3 feet wide, and 14 inches deep, and tapers to an abrupt and rounded end, which is sharp, somewhat like the Indian canoes of the Western Indian. The whole was hewn from a solid log of white pine about fourteen feet long.

PART OF A DUGOUT CANOE

Found at Cherry St., New York. The only known fragment of a canoe used by the Indians of Manhattan.

[1]Collection of the Rhode Island Historical Society, vol. 1, pp. 98-99, Providence, 1827.

The Indian children, shortly after birth, were bound to a stiff board, which served as a cradle, and there they were kept until they were able to walk and run about. This served the double purpose of supporting their backs and also of keeping them out of mischief.

The religion of the Manhattan and their neighbors was a nature worship, pure and simple. They believed that there were deities who dwelt in the four quarters of the compass, that the sun and moon, the thunder and the winds were various supernatural beings. That these were all controlled by a supreme god whom they called "Kickeron," or "Kickerom," was their conviction. They thought that the earth was populated by the descendants of a woman who fell from the sky and who would have been lost in the sea, save that a gigantic tortoise which afterwards became the earth, caught her on his back. They were also in fear of a terrible evil power, a horned snake, to whom they made sacrifices by burying objects in the ground in its name.

The Manhattan and their neighbors also believed in a future existence, placing their Elysian fields in the southwestern skies, where they believed the souls of their dead journeyed. It was for this reason that they placed food and implements in their graves with the bodies, so that the wandering soul might lack nothing necessary to its comfort on the trip.

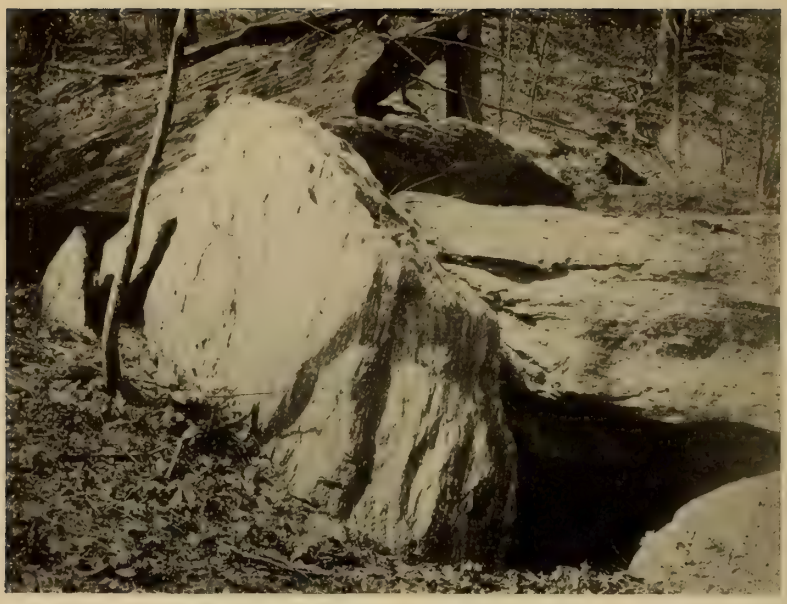
The religion of the Indians was marked by periodic ceremonies, one of which has come down to the present day among the modern remnants of the Shinnecock of Long Island and the Mohegan of Connecticut. This is the "June Meeting" which was formerly a ceremony held for the green corn. The Delaware in Oklahoma and Canada still perform a number of other annual ceremonies.

The old writers tell us that each Indian had some such name as "Buck's Horn," "Wildcat," or "Rattlesnake," and that when he died it was considered sacrilegious ever to mention his name again. It is also known that polygamy was practised by the local Indians.

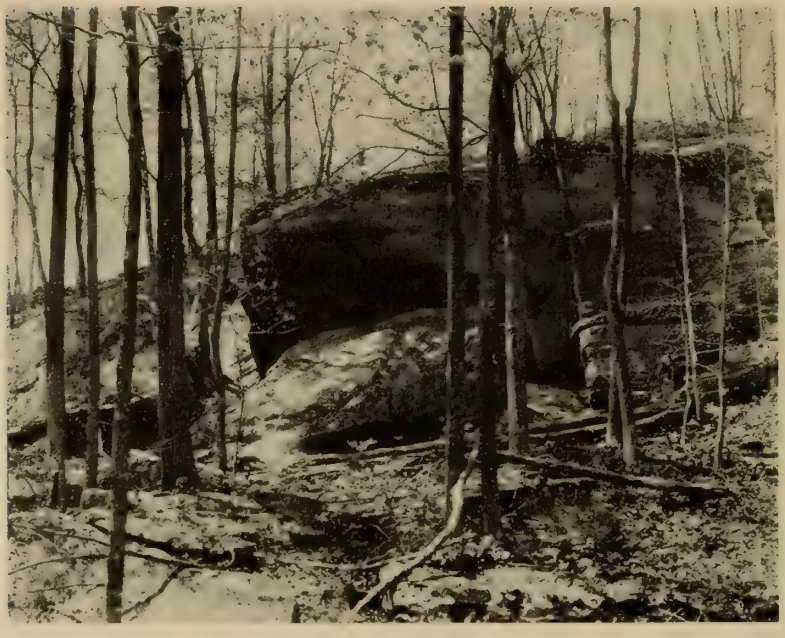
The Archaeological Exhibits.

So much for the ethnology of the Manhattan and their neighbors. Let us now turn to their archaeology as set forth by the specimens on view in the entrance of the Woodland Hall.

On entering the Eastern Woodland Indian Hall the visitor will find that the first table sections are devoted to an exhibition, as comprehensive as possible, showing the life of the natives in prehistoric times by means of



INWODD ROCK-SHELTER, MANHATTAN



FINCH'S ROCK HOUSE

specimens obtained from the ancient village and camp sites. Here may be seen remains of the various animals, fish, and shell-fish upon which the Indians depended for subsistence; fragments of nuts, corn, roots, and other food products, preserved by charring, and obtained from ancient fireplaces; and such implements as arrow points of antler and stone, net-sinkers of stone, and stone hoes for tilling the field, all illustrative of primitive methods of hunting and agriculture. Implements exhibited in the same case show the preparation of animal and vegetable food with primitive utensils, while close by are tools used by the Indians in preparing skins. The manufactures of the Indians are illustrated in the immediately adjacent section.

A progressive series of implements shows the making of an arrow point from a simple quartz pebble such as might be picked up anywhere on the shore, with the various stages leading to the finished point; the tools employed are also exhibited. Implements of stone for pecking, grooving, and polishing; hatchets and axes; pottery fragments, and household utensils, such as hammers, axes, adzes, and gouges, will be found at hand.

In the upright cases there is an exhibit from Manhattan Island, made up of specimens principally collected by Messrs. Alexander C. Chenoweth, W. L. Calver, and R. P. Bolton, in the rock-shelters and village sites at Inwood, showing as fully as possible the life of the pre-historic Manhattan Indians.

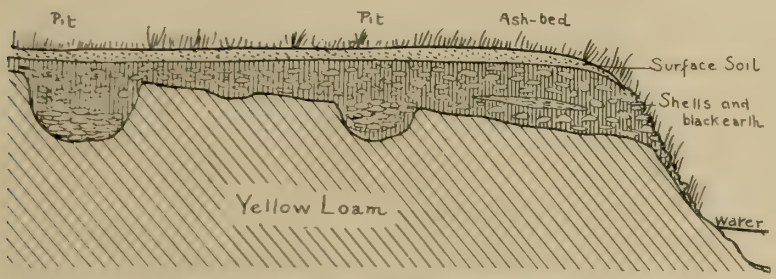
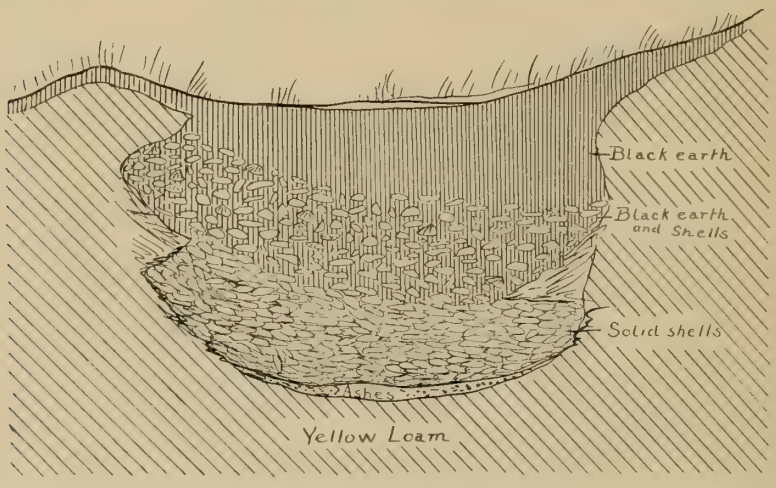


DIAGRAM OF A TYPICAL SHELL DEPOSIT

In another table case are to be seen implements and remains from the shell-heaps marking a long-forgotten Indian village at Shinnecock Hills, Long Island. This exhibit, which is one of the most complete of its kind, gives a rather adequate picture of the ancient life of these people and is especially valuable for the number and variety of primitive manufactures shown. One of the most interesting of the sections demonstrates, by means

of a series of specimens, the primitive methods of cutting bone and antler employed by these Indians. Bone was cut by notching or grooving it with a stone knife or flake, and then breaking it at the groove. Antler was worked in the same way, but it is very probable that the Indians boiled antler in order to make it more pliable and easily cut.

From the appearance of pottery fragments now to be found on the sites of the ancient Indian villages of this vicinity and the methods of modern Indian pottery makers, we may safely conclude that most, if not all, of the earthenware manufactured in this locality was made by the coil process, which consisted of the following steps: The Indians first secured clay of a suitable quality, which was mixed with pounded shell or stones to make it tougher and more durable. It was then worked into long rolls, and the Indians, beginning at the bottom, worked the pot up by adding coil after coil, blending or smoothing the coils with a smooth stone until they did not show from either the interior or exterior surface. When the pot was completed, it was decorated by stamping or incising designs about the exterior of the rim.



CROSS SECTION OF A SHELL PIT

The upright case at the end contains an exhibit from the remnants of the Algonkin and Iroquois Indians of New York State and New England, while a map showing the location of most of the Indian villages of Greater New York and vicinity and an actual section of a typical shell-heap, as well as photographs and labels describing the opening and excavation of the

sites, are near at hand. Specimens typical of those found in the shell-heap are also exhibited.

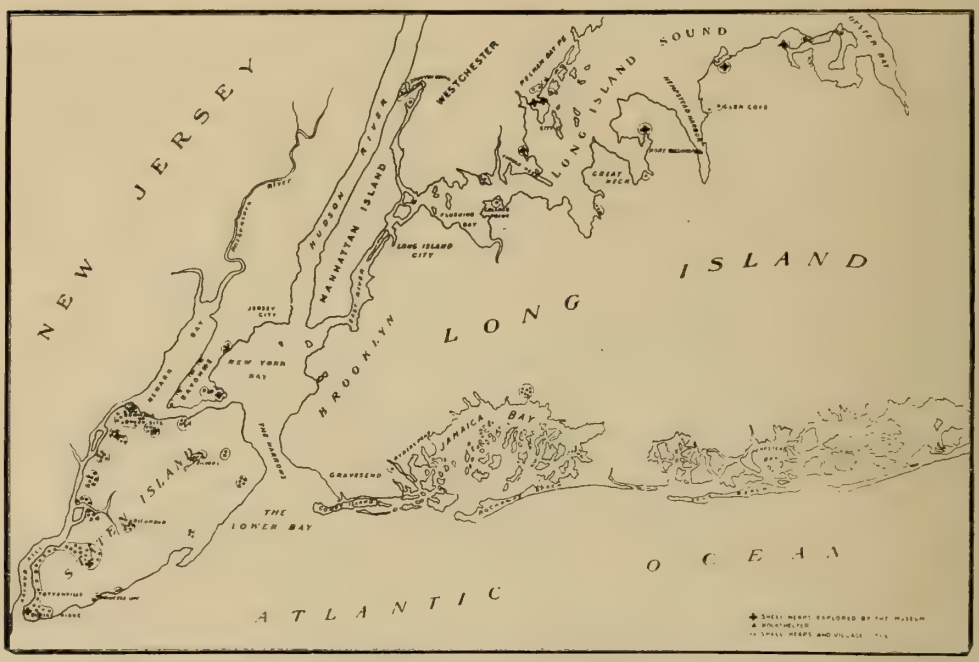
Of all the traces left by the aborigines along the New York seacoast, the most abundant and familiar are the shell-heaps. These are beds of refuse marking the sites of ancient villages, camps, and isolated wigwams. Wherever the fresh water joins the salt, especially where open water for fishing and a spring for drinking come together in happy combination, there is generally to be found some such evidence of Indian occupation.

The typical "shell-heap" is not a heap at all, for leaf mold, the wash from neighboring high ground, and often cultivation have generally made it level with its surroundings (page 14). Very often, unless the land be plowed, no shells whatever show on the surface, and the only way of finding out the condition of things below the sod is to test with a spade or a crowbar. If shells are present, their crunching soon gives notice of the fact. Sometimes shell-heaps have been located by shells thrown from animal burrows, or washed out by the rain, or in banks broken down by the surf. Some have been found fronting on the open Sound, but such cases are rare. These deposits consist of large quantities of decayed oyster, clam, and other marine shells mixed with stained earth, with ashes, charcoal, and fire-cracked stones to mark the spots where ancient camp fires blazed. Among the shells are usually scattered antler of deer, bones of animals, fishes, and birds, quantities of pottery fragments, and broken implements; in short, the imperishable part of the camp refuse left by the Indians. Now and then, perfect implements, and ornaments that had been carelessly lost in the rubbish or hidden for safe-keeping are discovered.

Shell-heaps vary from a few inches to four feet in depth, and in area from a few square yards to several acres—all depending on the length of time the settlement was occupied and the number of dwellings comprising it. Deep shell-heaps are often divided into layers, the lowest of which are, of course, the oldest. Under and near most of these deposits may be found scattered "pits" or fire holes, which are bowl-shaped depressions in the ground filled with layers of stained earth, shells, and other refuse, with an occasional layer of ashes. Some pits are as large as ten feet wide by six feet deep, but the average is four feet deep by three feet wide. It is supposed that they were used as ovens or steaming holes and afterwards filled up with refuse. Some contain human skeletons, which may have been interred in them during the winter season when grave digging was impossible. These pits generally contain more of interest than the ordinary shell-heap. The closely packed regular masses of shells form a covering which tends to preserve

bone implements, charred corn, and such perishable articles from decay in a way that the looser shells of the general layers fail to do.

Shell-heaps, while abundant along the seacoast, are seldom found inland, except on salt creeks or other streams having access to salt water. They may be seen all along the east shore of the Hudson River at more or less frequent intervals as far up as Peekskill; on Croton Point and between Nyack and Hook Mountain on the west shore they attain considerable size. There are a few small deposits, however, composed mainly of fresh water clams (Unio) situated on fresh water lakes in the interior of Westchester



MAP GIVING THE LOCATIONS OF SHELL DEPOSITS

Those marked + have been explored by the Museum

County. There are many shell-heaps on Staten Island. Shell-heaps occur or did occur on Constable Hook, New Jersey, and at intervals between there and Jersey City along the western shore of New York Bay. The accompanying map gives the location of the important known shell deposits in the vicinity of New York City.

Besides the shell-heaps, the ancient cemeteries of the Indians hold much of interest to the archaeologist.

Although most of the natives in the vicinity of Greater New York did not place objects in the graves with their dead, some graves at Burial Ridge, Tottenville, Staten Island, when opened for the Museum in 1895, were found to contain a great many interesting and valuable remains. With the skeleton of a child there was a great deposit of utensils, both finished and unfinished ornaments, such as beads, pendants, and the like, a stone pipe,

INDIAN SKELETONS PIERCED BY ARROW POINTS, TOTTENVILLE, STATEN ISLAND

and a number of other objects, while not far away the skeletons of three Indian warriors were exhumed, in and among whose bones there were found, as shown in the cases devoted to the archaeology of Staten Island, twenty-three arrow points of stone, antler, and bone.

BONES PUNCTURED BY ARROW POINTS, FROM SKELETONS FOUND ON STATEN ISLAND

This is an exhibit which excellently indicates the use of the bow in Indian warfare. In the first skeleton, it was found that two arrow points of antler and one of bone had pierced the body and lodged near the spinal column. Another point of argillite had been driven between two ribs, cutting a notch in each. A bone arrow point had struck the shoulder and was resting against the scapula. Among the bones of the right hand, an arrow point of antler was discovered, and there was a similar one near the left hand. Another antler point was lying in the sand just beneath the body and had, no doubt, dropped from it when the flesh wasted away. The most interesting wound of all was one where an antler-tipped arrow had plowed through one side of the body and fully one-third of the point had passed through one of the ribs, making a hole, in which it remained. The second warrior was also terribly injured. The left femur showed an elongated puncture near the lower end, probably made by an arrow point. Among the ribs was the tip of an antler point, and another of yellow jasper was among the ribs on the left side of the body. Three other points were among the bones. The third skeleton was likewise an example of old-time bow play. There was an antler point among the ribs of the left side. The end of one of the fibulæ was shattered by a stone arrow-head, and a second point had lodged between two ribs. Beneath the sternum was a flint point, and the right shoulder blade showed a fracture near the end, caused by a blow of some hand implement or an arrow. Near the base of the skull, the end of an antler arrow-head was discovered, broken perhaps by its impact with the occiput. Two bone points were near the lower bones of the left leg. A second point was found upon search among the left ribs; under the vertebræ was the base of another antler point, and two broken points were found beneath the body.

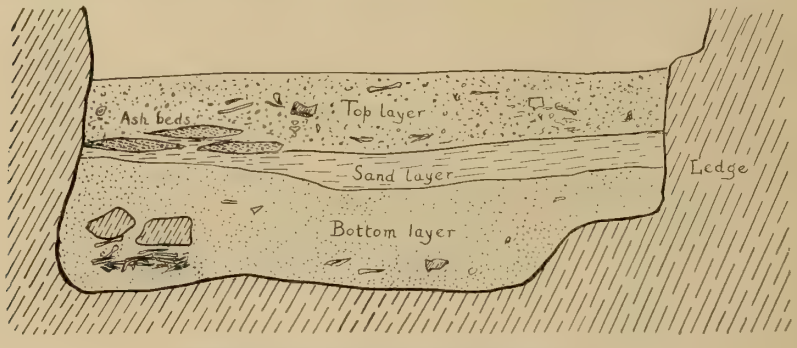
The positions in which several of the points were found certainly speak well for the great force which propelled them. The long bows of the local Indians must indeed have been formidable weapons. Taking into consideration the number of arrows which must have been imbedded in the bodies of the warriors, it is perhaps probable that the majority of the projectiles were driven into the victims at close range after death.

In a small square case will be found the model of a rock-shelter and typical objects found in such places. These rock-shelters, as the name implies, are protected spots in rocky ledges, which Indians once made more or less permanent places of abode. Many such shelters exist in the vicinity of New York, two or more having been discovered at Inwood, Manhattan. The most important rock-shelter so far discovered is the so-called Finch Rock

House reproduced in a model. The original is near Armonk, Westchester County, New York. One point of special interest is the fact that the Finch shelter contained two layers bearing relics separated by sand as shown in the drawing. As no pottery was found in the bottom layer, it has been inferred that we have here the remains of two different races of Indians, the older not yet advanced to the pottery-making stage. This conclusion, is, however, far from final, for the whole arrangement may be due to accident.

In the table cases opposite those devoted to the Algonkin some sections are used to show the life history of the Iroquois tribes of western New York, and the following section shows, as well as possible, the culture of the Five Nations and objects used by the Indians of New York State obtained from European traders after the advent of the settlers.

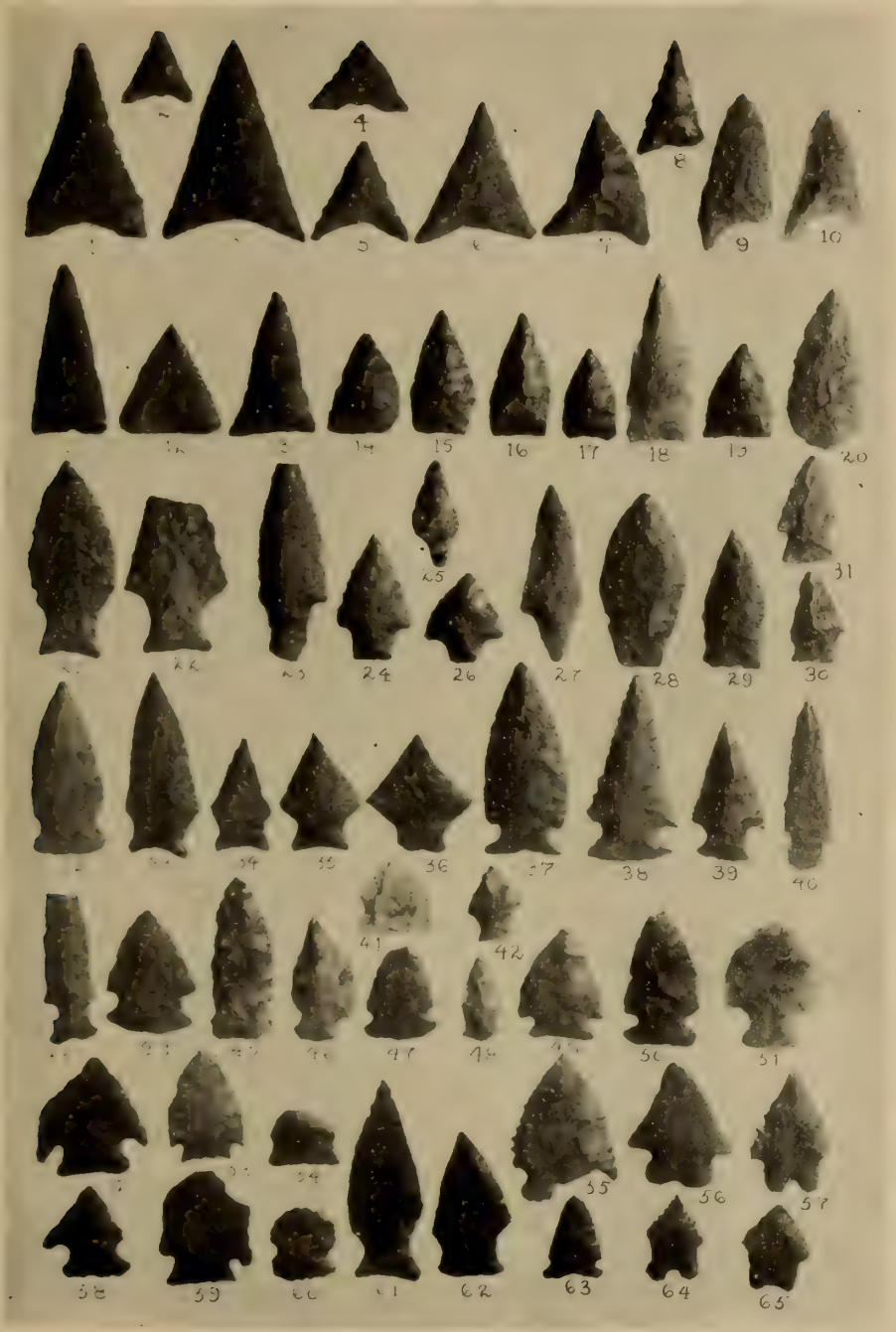
With the Iroquois exhibit is a special exhibit showing typical wampum beads, belts, and implements illustrating the prehistoric manufacture of wampum on Long Island.



VERTICAL SECTION IN FINCH'S ROCK HOUSE, ABOUT MIDWAY OF THE CAVE

TYPES OF INDIAN RELICS FOUND IN AND ABOUT NEW YORK CITY

HAVING now taken a general view of the exhibit, the visitor may be interested in a study of the several kinds of relics found in this locality. As these types are somewhat unlike those found in near-by regions, we conclude that the Indians formerly living here had habits and customs different from those of their neighbors. For want of a better name, these long-extinct tribes have been called collectively the New York Coastal Algonkin. The term Algonkin designates the language they spoke, while the adjectives define their habitat. Under the designation New York



TYPES OF ARROW POINTS

Coastal Algonkin, the writer includes the tribes along the coast from Tottenville, Staten Island, the extreme southern point of the state, to the Connecticut boundary on Long Island Sound, including to a certain extent the shores of New Jersey immediately adjacent to Staten and Manhattan Islands, the east bank of the Hudson River as far north as Yonkers, and the Western end of Long Island.

From the examination of the remains of the New York Coastal Algonkian area preserved in many collections, both public and private, it becomes obvious that the objects found may be roughly divided into three groups: articles of stone, articles of bone and antler, and articles of clay, shell, and metal. The first group is, from the imperishable nature of its representatives, naturally the largest and comprises a number of sub-groups to be briefly described and commented upon in this paper. Examples of this type will be found in the table cases previously mentioned. For the following descriptions and historical notes the author has largely drawn on Mr. James K. Finch's and his own contributions to Volume III of the "Anthropological Papers of the American Museum of Natural History" (New York, 1909).

Chipped Articles.

Arrow Points. Two general types of arrow points may be recognized: these are the stemmed, or notched, and the triangular forms. The former are by far the most abundant, and while these are usually made of the nearest local rock possessing the necessary conchoidal fracture, in some cases they are of material brought from a long distance. Specimens made of pink flint resembling stone from the Flint Ridge of Ohio, and of jasper found to the south of this region, have been recorded. Blunt arrow points are rare, the Indians probably preferring wooden arrows for this type. Many of the so-called "blunt points" found in collections appear to be scrapers made over from broken arrow points of a large size.

The triangular type has long been regarded by the local collectors of this vicinity as being the type used in war, the argument being that as it has no stem, it was necessarily but loosely fastened in its shaft and, if shot into the body, would be very liable to become detached and remain in the flesh if any attempt were made to withdraw it by tugging at the shaft. While it was no doubt perfectly possible to fasten a point of triangular shape to the shaft as firmly as a notched point, the discoveries of Mr. George H. Pepper at Tottenville, Staten Island, where twenty-three arrow points were found in and among the bones of three Indian skeletons, tend to strengthen this

KNIVES AND SCRAPERS

theory. While the majority of points found there were of bone or antler, all those made of stone were of this type; indeed, most of the bone points were also triangular in shape. However, it is well to bear in mind that arrow points of triangular type were used for every purpose by all the early Iroquois tribes of New York.

Spear Points and Knives. None of the early accounts of contemporary European writers seems to mention the use of spears (other than bone or antler-headed harpoons) by the Indians hereabouts, and it is probable that the larger arrow-point forms found were used as knives or cutting tools. They are usually notched or stemmed, rarely triangular, and occasionally round or oval. They vary in size, but it must be remembered that one tool may have had various uses, and that drills, knives, and scrapers may often have been combined in one implement.

Scrapers. Scrapers were probably used in dressing skins, in sharpening bone implements, wood-working, and for various other purposes. These are usually mere flint flakes chipped to an edge on one side. Nevertheless, notched and stemmed forms requiring some care in their making, do occur. Broken arrow points were occasionally chipped down to serve this purpose. A single serrated scraper has been found. These are very rare in both the Algonkian and Iroquois areas of New England and the Middle Atlantic States. One very large stemmed scraper, of a type more common in the far west, also comes from this locality.

Drills. These are usually chipped tools presenting an elongated narrow blade and a considerably swollen or expanded base, suitable for grasping in the hand. In some cases the base was absent and those were probably hafted in wood. Specimens with blades having a square or rectangular cross-section are very rare. The finding of cores left in half-drilled objects shows the use of a hollow drill, and it has been suggested that a hard hollow reed used with sand and water on a soft stone would produce this effect. To bear out this assertion, it has been reported that a half-drilled implement has been found outside this area on the upper Hudson in which the remains of the reed drill were found in the cavity left by its action.

Rough Stone Articles.

Hammerstones. These vary from simple pebbles picked up and used in the rough, showing merely a battered edge or edges acquired by use, to the pitted forms. They are generally mere pebbles with a pit pecked on two opposite sides, perhaps to aid in grasping with the thumb and forefinger.

DRILLS, SCRAPERS AND OTHER OBJECTS

Some have battered edges, but many have not, suggesting, when round and regular, a use as gaming or "Chunké" stones, or as implements used only in pounding some rather soft substance. Hammerstones, pitted on one side only, and others with many pits on all sides, occur. These latter may have had some special use, and are not to be comfounded with the large, flat, slab-like stones having pits only on one side, found in other regions, and perhaps used as receptacles for holding nuts while cracking them. While these are common in the Iroquoian area, they are unknown here.

Large stones, single or double-pitted, resembling over-sized hammerstones, occur. These may have been used as anvils in chipping flint or for like purposes.

Grooved clubs or mauls, also showing use as hammers, are found. These are rare and are usually either rough pebbles, grooved for hafting, as in the case of the grooved axe, or grooved axes, the blades of which have become so battered, broken, and rounded by wear as to preclude their further use for chopping.

Net-Sinkers. On all sites near the water, either salt or fresh, net-sinkers show the prevalence of fishing. These are of two types. In one case a pebble is notched on opposite sides of either the long or broad axis; in the other, a groove is pecked around the entire pebble in the same manner. The latter type is comparatively scarce, as the former, being more easily and quickly made, was just as useful to the savage. The modern Cree and Ojibway, residing in the forests north of the Great Lakes, still use pebbles for this purpose, but those observed by the writer were not notched or worked in any way. Occassionally, sinkers notched on both axes are found in this region.

Hoes. These are usually ovoid implements, chipped from trap rock, sometimes notched to facilitate hafting, and sometimes not. They usually show a slight polish on the blade, caused by friction with the ground. This type of stone hoe is the form mentioned by early writers; but perhaps hoes of shell, bone, or tortoise shell, and wood were used also. None of these, however, are still in existence.

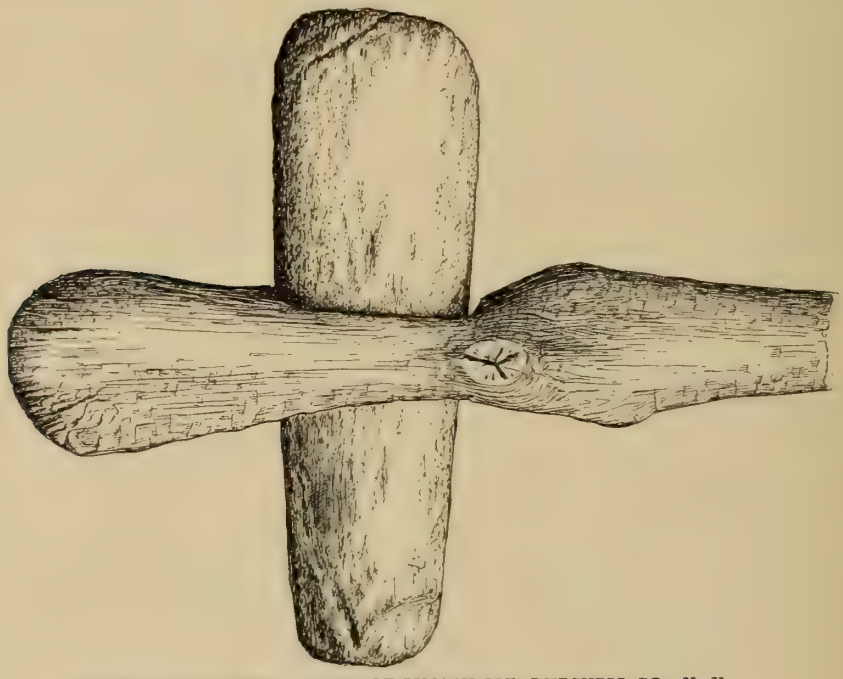
Hand Choppers. Pebbles chipped to an edge on one side, for use as hand choppers, occur. These are occasionally pitted on both sides.

Grooved Axes. For the purposes of this paper, the writer, while aware that many grooved axes are well made and polished, has decided to include them under the head of "Rough Stone Articles," as by far the greater majority of the grooved axes and celts from this region lack the polish and finish belonging to other articles later to be described. Grooved axes are of

TYPES OF STONE AXES AND CELTS

two sorts: *a*, those made of simple pebbles, merely modified by grooving and chipping or pecking an edge; and *b*, axes which have been pecked and worked all over and sometimes polished. The latter (*b*) may be said to include:

1. Groove encircling three sides of blade, one side flat.
2. Ridged groove encircling three sides of blade, one side flat.
3. Groove encircling three sides of blade, longitudinal groove on flat side.
4. Groove encircling three sides of blade, longitudinal groove on flat side and opposite.



HAFTED CELT FROM A POND AT THORNDALE, DUTCHESS CO., N. Y.
Length of celt 16.6 cm.

5. Groove encircling blade.
6. Ridged groove encircling blade.

A seventh type, having a double groove encircling the blade, may occur in this territory, but has never been reported. A specimen from the Hudson River region, just north of the area here dwelt upon, is in the Henry Booth

Collection in this Museum. While most worked stone axes have been pecked into shape, a few have been fashioned by chipping but these seem to be rare.

Grooved axes were hafted in various ways. During the summer of 1908, the Eastern Cree living in the vicinity of the southern end of Hudson Bay told the writer that their ancestors, who made and used such axes, hafted them by splitting a stick and setting the blade in it, then binding the handle together with deerskin (probably rawhide) above and below the split. No specimens of the grooved axe in the original haft seem now to be extant from any locality in the East. From the battered appearance of the butts of these axes, it may have been that they were sometimes used in lieu of mauls or hammers. It is possible that they may have been used in war. It is generally supposed that in cutting down trees, making dug-out canoes, and other kinds of wood-working, fire was used as an adjunct to the stone axe, the former being the active agent. The process of burning and charring having gone on sufficiently, the stone axe was used to remove the burned portion. However, some stone axes seem sharp enough to cut quite well without the aid of fire.

Celts. Ungrooved axes or hatchets, usually called celts, are frequent throughout this area; but are nowhere as abundant as the grooved axe, especially near the southern border of the region. The grooved axe seems to have been the typical cutting and chopping tool of the local Algonkin. The widespread idea that the celt was sometimes used unhafted as a skinning tool, has no historic proof, but may possibly have some foundation. The Cree of the southern Hudson Bay region use an edged tool of bone for this purpose, a fact which is somewhat suggestive, although the implement differs in shape from the celt. Celts with one side flat and the other beveled to an edge may have been used as adzes. From the worn and hammered appearance of the polls of some celts, it is possible that many of these implements were used as wedges in splitting wood, after constant manipulation in their chopping capacity had permanently dulled their edges.

The celts of this region are, as a general thing, poorly made, a pebble of suitable shape having an edge ground on it with little or no preliminary shaping. More rarely, however, they were carefully worked all over by pecking and polishing, as in the case of the grooved axe.

In type, aside from the general division of rough and worked celts, we may add that most celts in this region have slightly rounded polls, the bit broader than the butt, although some exceptions have been found. The forms are as follows: *a*, rough stone celts, pebbles with one end ground to an

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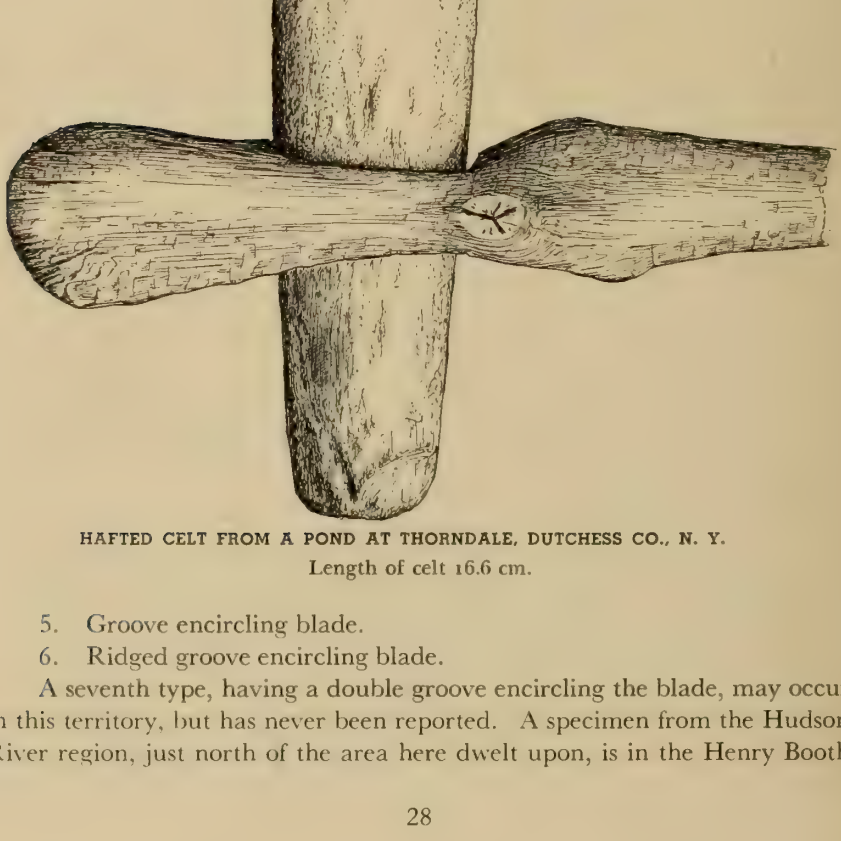

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In type, aside from the general division of rough and worked celts, we may add that most celts in this region have slightly rounded polls, the bit broader than the butt, although some exceptions have been found. The forms are as follows: *a*, rough stone celts, pebbles with one end ground to an

edge, but otherwise scarcely worked; and *b*, worked stone celts, which include the following:

1. Wedge-shaped, poll narrower than bit, and angles rounded. Common.

2. Like number one, but with bit much broader than poll. Cross-section oval. Very rare.

3. Like number one, but one side flat, other beveled at one end to make a cutting edge.

4. Like number two, but with cutting edge flaring, broader than body. "Bell-mouthed type." Very rare.

North and west of this region we find the Iroquois territory, where most worked celts are angular, having almost invariably a rectangular cross-section and squared butt. Types 1 and 3 also occur, but the celt with the rectangular cross-section seems most typical of the Iroquoian region. Many small celts, made of flat fragments or chips of stone, are also found in this area, and these could scarcely have had a use as chopping tools.

In the Niagara watershed and extending eastward as far as the Genesee Valley, an angular adze-like form having a trapezoidal cross-section occurs. It is found principally in what was the territory of the Attiwandaronk, Kah-Kwah, or Neutral Nation (an Iroquoian tribe, early annihilated by the Five Nations). It also occurs as has been stated, on the sites of villages of the Iroquois proper, but is not abundant. South of the Iroquois in Central Pennsylvania, another form which does not occur in this region is the chipped celt, usually of flint or other hard stone. This form is, however, frequent in the country about the headwaters of the Delaware.

In the "American Anthropologist," Vol. 9, No. 2, p. 296, *et seq.*, Mr. C. C. Willoughby has figured and described the celts of the New England region with remarks on the methods of hafting employed. These seem to be two in number, and consist, in the case of the larger forms, of setting the blade through a hole in the end of a club-like handle, the butt or poll projecting on one side and the blade on the other as in one which was found in the muck of a pond bottom at Thorndale, Dutchess County, New York, a region once in the Mahikan territory. Smaller celts were set into a club-like handle, the butt resting in a hole or socket.

Adzes. These seem to be of two kinds, the first and most simple being celt-like, but flat on one side, the other side being beveled to an edge on one side. The second form differs in having a groove, which is not infrequently ridged. Occasionally, adzes with two parallel grooves occur. They were

BANNER STONES, GORGETS, AND AMULETS

probably hafted by taking a stick at one end of which projected a short arm at right angles with the shaft, laying the flat side of the blade against this arm and binding it on with sinew, thongs, or withes. The groove, of course, was of aid in securing the blade to the handle. Adzes of stone, hafted in this manner, have been obtained on the North Pacific Coast. The celt adze seems not uncommon, but the grooved adze is rare, neither form being nearly so abundant as in the New England region.

Gouges. The stone gouge is rare, and seems always to be a plain, single-bladed affair without the transverse grooves so frequently seen in New England specimens, and hereabouts is always easily distinguished from the adze. Less than half a dozen specimens have been seen by the writer from this entire area, although probably quite as much work in wood was done by the New York Coastal Algonkian as by the New England Indians.

Pestles. The long pestle occurs throughout the region of the Coastal Algonkin of New York, but is nowhere as abundant as in New England. They seem always to have been used with the wooden block mortar hereabouts, and are mentioned by the early writers as part of the household equipment of the natives. They do not seem to have been used by the Iroquois to the north and west of this area either in early or later times. The wooden pestle of dumb-bell shape seems to have been preferred by them. The latter is used by the Canadian Delaware and may have taken the place of the long stone pestle to a great extent in this region.

Mullers, Grinders, and Polishing Stones. These are frequent, and consist merely of rounded pebbles, shaped and worn by use, probably most often in crushing corn. They are mentioned by De Vries as being used by the Indians with a flat stone slab for grinding corn when traveling. Some seem to have been used for polishing stone implements, but it seems hard to draw the line, as the appearance gained from friction would be quite similar. Such mullers and their attendant slabs, used for preparing cornmeal have within a few years been collected in use among the Oneida Iroquois of New York, one specimen being in the American Museum collection.

Sinew Stones. These are pebbles showing grooves along the edges, popularly supposed to have been worn there by rubbing thongs and sinews across the edges to shape them. They occur generally, but are not common.

Stone Mortars. These are common, but rather local, some sites having none at all, and others a good many. One locality on Staten Island is

notable for the numbers found there, whereas they are rare elsewhere in that vicinity. They may be divided into the following types:

1. Portable mortar, hole on one side.
2. Portable mortar, hole on both sides (New Jersey type).
3. Portable slab mortar or metate, used on one or both sides.
4. Boulder mortar, one or more holes, immovable.

The first two types are the most abundant, the third is not uncommon, but the fourth is very rare, only one or two being reported. As above stated, De Vries claims that the portable mortars were used in bread-making while the Indians were traveling, but certainly the majority of those found are far too heavy for this purpose.

Pigments and Paint Cups. Fragments of pigments such as graphite and limonite, showing the marks of scratching with scrapers, are found. These have apparently supplied the material for painting. Worked geodes are common on many sites. These show traces of chipping in some instances and may have been paint cups. There is a tiny pestle-shaped pebble in the Museum collection from Westchester County, which is said to have been found with a geode of this type. The popular theory is that such geodes were used as "paint cups" and this seems probable.

Stone Plummets. These are very rare, in contrast to their abundance in the New England region. They consist usually of small worked egg-shaped stones, grooved at one end, probably for suspension. The writer has seen but one from this area. Their use is problematic.

Semilunar Knives. Knives of rubbed slate, similar in appearance to the ulu, or woman's knife of the Eskimo, are found, though rarely, in this region. While sometimes ascribed to Eskimo influence or contact, it is possible that this form (which occurs throughout New England), judging by its distribution, may have been native to the Eastern Algonkin also. The Eastern Cree still use knives of this type as scrapers. Like most other forms common in New England, it is less abundant in the southern part of this area.

Stone Beads. Various pebbles generally perforated naturally are to be found on some sites, and may or may not have been used as beads or pendants. On Staten Island, at Watchogue, Mr Isaiah Merrill once owned a number of square beads of pinkish steatite (?), all but one of which have been lost, and which he claims were found on his farm.

Gorgets. Two types of the gorget occur. These are the single-holed pendant form, which is the less abundant of the two, and the double-holed type. The latter is flat, rectangular in shape, and generally well polished. It usually has two perforations a short distance from the middle. The modern Lenapé of Canada claim to have used these as hair ornaments. Probably the two-holed variety is typical of the Algonkian peoples of this region; the single-holed form, on the other hand, is the most abundant on old Iroquoian sites. Specimens of the latter have been obtained in use among the Canadian Iroquois, and some of them are in the Museum collections.

Amulets. Certain problematic articles of the "bar" and even "bird amulet" type have been found, but these are probably exotic in origin and are not characteristic of the archæology of the region in question.

Banner Stones. These beautiful polished stone implements of unknown use may be divided into three great classes, with several sub-types as follows:

1. Notched banner stones.
2. Grooved banner stones.
   a. Groove on both sides.
   b. Groove on one side.
3. Perforated banner stones.
   a. Plain.
   b. Butterfly.

All three types seem equally abundant, but the notched banner stones appear to be the oldest form and occur under circumstances pointing to great relative antiquity. They are found, however, on the more recent sites as well. Both the notched and the grooved banner stones are usually more rough in appearance than the perforated type, and the writer has never seen a polished specimen of the first class. On the other hand, the grooved variety frequently exhibits the high degree of finish characteristic of the perforated forms. Banner stones grooved only on one side are less common than the other forms. While the latter class is generally made of slate, steatite, or some similar soft and easily worked material, the notched and grooved forms, especially the former, are often formed either from naturally-shaped pebbles or chipped roughly into shape. Implements, usually naturally-shaped stones with little working, without notches, grooves, or perforations but greatly resembling the notched and grooved banner stones in shape, are not infrequently found in aboriginal sites hereabouts

and may have served as banner stones. There seem to be neither records nor palusible theories as to their use.

Pipes. Stone pipes, invariably made of steatite, are very rare. Four types have been noted as follows:

1. Monitor or platform pipe, platform not projecting before the bowl.

2. Monitor or platform pipe, platform projecting before bowl, with or without tiny carved stem or mouthpiece. Of the latter, only one specimen is known.

3. Trumpet-shaped stone pipe.

4. Rectangular stone pipe, human face carved on front of bowl.

It may be remarked that more stone pipes have been reported from the Indian cemetery at Burial Ridge, Tottenville, Staten Island, than from all the rest of the area put together. The second and third types are represented by one specimen each from Burial Ridge and from nowhere else in this region. Four or five pipes of the first class have been found there as well. The last class is by a single specimen represented obtained by Mr. W. L. Calver at Inwood, Manhattan Island. Undoubtedly the clay pipe was the most common form used in this locality.

Steatite Vessels. These are not at all abundant, though occurring almost everywhere. They were doubtless all imported from New England, as there are no steatite quarries within the range of the New York Coastal Algonkin. The single form found is that common in the East, an oblong, fairly deep vessel with a lug, ear, or handle at each end. Occasionally, such vessels are ornamented by rude incisions along the rim.

Articles of Clay.

Pottery Pipes are common everywhere. They are usually manufactured of a better quality of clay than that used for vessels, and bear fairly similar designs. They are susceptible of division into the following classes:

1. Straight tubular form, bowl expanding slightly.

2. Bowl much larger than stem, leaving it at an angle of forty-five degrees. Stem round.

3. Same as number 2, but stem angular and much flattened.

4. Effigy pipes (represented by a human head apparently broken from a pipe bowl, obtained by Mr. M. R. Harrington at Port Washington, Long Island.)

The straight pipe seems to have been obtained only on Staten Island, on the north shore, in the region occupied by the Hackensack. While nowhere as abundant as upon the Iroquoian sites of central and western New York, the clay pipe is rather common and is a prominent feature in the coast culture of New York. It is more abundant perhaps in the southern part of the area, but this may well be due to the fact that data from this region are more easily accessible. The triangular-stemmed "trumper" pipe so common on the Iroquoian sites is unknown in this region.

Pottery Vessels.

The pottery of this region may all be considered as being either the native Algonkian in type or showing Iroquoian influence with a third and intermediate variety. Algonkian vessels may be divided into the following groups according to shape:

1. Conical, pointed bottom, slightly swollen sides, circumference largest at the mouth,—the typical Algonkian pot of this area. Fig. a.

2. Like number 1, but much rounder and broader, Fig. b.

3. Bottom pointed, sides slightly swollen, neck slightly constricted, Fig. c.

4. Identical with number 2, except that just below the beginning of the neck, occur small raised lugs, ears, or handles. This is rare from this area, Fig. d.

5. Rounded bottom, somewhat constricted neck, lip sometimes flaring, or even turning down and back, Fig. e.

The intermediate types are as follows:

6. Rounded bottom, constricted neck, narrow raised rim or collar, Fig. f.

7. Like number 6, but with sides more elongated and bottom more oval than round, heavier collar, generally notched angle, with or without a series of small humps or projections at intervals, Fig. g.

The Iroquoian types are as follows:

8. Mouth rounded, collar or rim heavy, with humps or peaks at intervals, angle notched, neck constricted and bottom rounded, can stand by itself, an unknown feature in local Algonkian vessels, Fig. h.

9. Same as number 7, but with mouth square, and humps at every angle. Much less common than in the preceding, Fig. i.

In size, the vessels range from small toy-like pots to jars of very large capacity. In general they appear to have been made by the coil process, and are tempered with pounded stone or fine gravel, mica or burned or

pounded shell. Sherds showing tempering by fiber or some other substance that disappeared in firing are found rarely. When vessels were cracked or broken, a series of holes was bored opposite each other on either side of the break and the parts laced together, rendering the vessel capable of storing dry objects, at least.

POTTERY FORMS OF THE CENTRAL ALGONKIN

Life forms are exceedingly rare in local ceramic art. From Manhattan Island and Van Cortlandt Park, there come a number of specimens showing incised human (?) faces. This is not an uncommon form on Iroquoian sites in Central and Western New York. On the Bowman's Brook site at Mariner's Harbor, Staten Island, fragments of a typically Algonkian pot were obtained which bore at intervals rude raised faces. With the sole exception of a rather well-modeled clay face, apparently, broken from the bowl of a pipe found at Port Washington, Long Island by Mr. M. R. Harrington, this

brief statement concludes the list of pottery life forms reported from this area, although others may yet be found here, since some interesting objects have been collected in immediately adjacent territory.

The forms of decoration consist of stamping with a stamp, roulette, or paddle, and incising. Occasionally, but very rarely, stucco work occurs. Under stamping we can enumerate the following processes:

1. Impression with the rounded end of a stick (rare).
2. Impression with the end of a quill, or hollow reed, leaving a circular depression with a tiny lump or nipple (rare) in the center.
3. Impression with a section of a hollow reed, making a stamped circle (rare).
4. Impression with finger nail (doubtful, but perhaps used on some sherds from Manhattan Island).
5. Impression of the edge of a scallop shell.
6. Impression with a carved bone, antler, or wooden stamp.
7. Impression of a cord, wrapped stick.
8. Impression with roulette.

Under the head of decoration by incision we can enumerate the following:

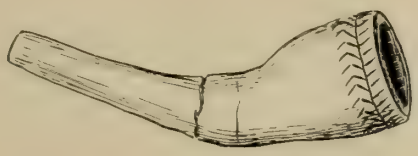
9. Incised decoration, probably made with a stick.
10. Incised decoration possibly made with a flint object (only one specimen at hand).

The paddle was frequently used to finish the sides and bottom of the pot by imparting an appearance of pressure with fabric when the clay was wet.

11. Stucco. Occasionally, ridges of clay placed on the rim for ornament appear to have been added after the shaping of the vessel.

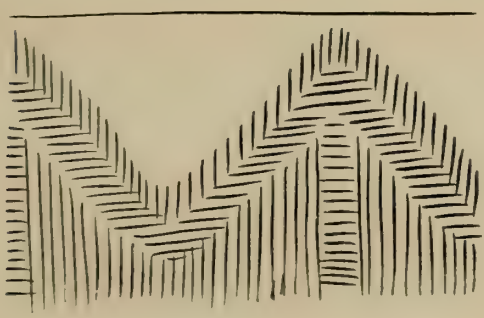
Ornamentation is usually external, and vessels, either Algonkian or Iroquoian, are rarely ornamented below the rim, although occasionally the designs run part way down the side in the case of the Algonkian forms. Where decoration has been applied by one of the stamping processes, and more rarely by incision, it is sometimes continued over the lip or rim for an inch or less on the inside. This only occurs in the typical Algonkian forms, and is never seen when incised ornamentation is used. The rims of Iroquoian vessels are never ornamented on the interior, nor is stamping so frequently practised on vessels of this class. The intermediate forms, at least the first of the two mentioned, are frequently ornamented on the interior of the lip. This internal decoration is much more common in the southern portion of this area than elsewhere in the vicinity.

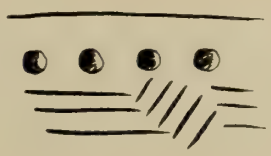
In design, we must of course give up all thought of trying to obtain symbolism, if such there were, for there are no sources now left upon which to base our assumptions. Certain conventional types of decoration seem to have been in vogue, usually consisting in rows of stamped or incised parallel lines and much more rarely of dots regularly arranged in the same manner. Zigzag, chevron, and "herring bone" patterns are the most common, but other angular forms occur, and rows of parallel lines encircling the vessel are sometimes to be found. Stamping and incising as decorative processes never seem to occur on the same vessel. Curvilinear decoration

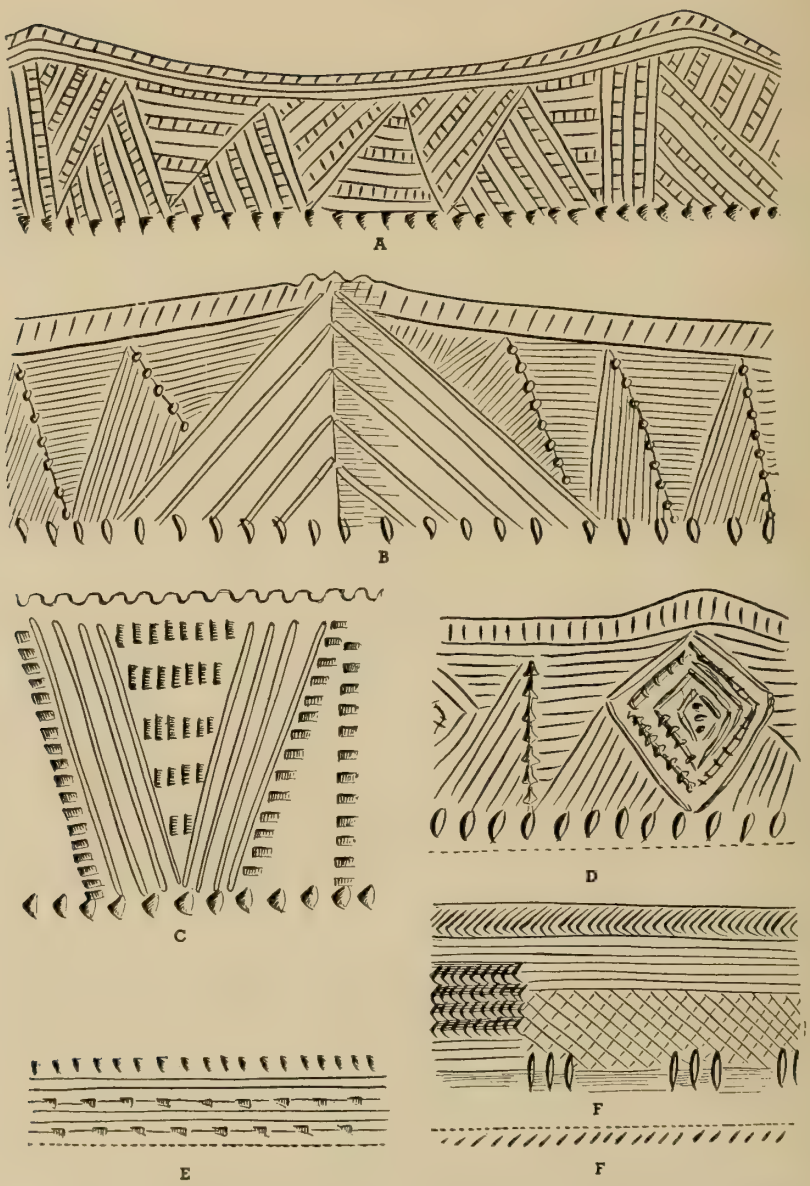


is exceedingly rare, and not enough material is at hand to show that patterns were used; possibly these were scrolls of some form. On account of the lack of material, it cannot be determined, except in a very general and unsatisfactory way, whether the designs on the Algonkian vessels differ from those on the Iroquoian.

The angle formed where the heavy rim or collar leaves the constricted neck of the Iroquoian vessel is almost invariably notched, and as such collars and angles do not occur on vessels of the true Algonkian type, this feature is necessarily absent from them. It is noticeable that Iroquoian vessels are usually decorated with incised designs, rather than stamped patterns.







a, *b*, and *d*, designs from Iroquoian vessels; *c*, and *e* designs from an Algonkian vessel; *f*, design from a vessel of the Iroquoian type from a Connecticut rock-shelter, introduced here for comparison.

Pottery is found abundantly on the majority of the sites in this district; but, while very much more common than in the New England area, it does not equal in abundance that from the Iroquois country. It is rarely found buried in graves with skeletons as in the Iroquoian area; when sometimes found in graves, however, it is usually at some distance from the human remains and apparently not connected with them. Whole or nearly whole vessels are exceedingly rare and the number of those found up to date may easily be counted upon the fingers. Potsherds taken from pits or shell-heaps, where they have not been exposed to the action of the weather, are often as thickly covered with grease as when they are broken and cast aside.

Articles of Metal.

Beads. Beads of native metal, consisting simply of pieces of hammered sheet copper rolled into small tubes, have been found, but they are very rare. Copper salts, but no objects, were found upon the bones, especially on those of the head and neck of a child's skeleton at Burial Ridge, Tottenville, Staten Island, which seemed to indicate the use of copper beads. A great many beads of *olivella* shell, some of them discolored by copper salts, were found about the neck of the skeleton. A single celt of copper is said to have been found in Westchester County, probably on Croton Neck, slightly above the limit of the territory treated in this paper.[1] A large number of copper beads of the type described were found with a skeleton on Constable Hook, Bayonne, New Jersey, and are now in the hands of a private collector in Brooklyn.

Articles of Shell.

Wampum. Objects of shell are not at all common, notwithstanding that the coast region of New York was one of the best known localities for wampum manufacture on the continent. Wampum beads are almost unknown from local sites. With the exception of completed beads, most of which may have been taken into the interior, by the Indians, wampum may be found in all stages of manufacture. We refer to the white wampum, for traces of the "black" (blue) wampum made from the hard clam or quahog are so far not reported. The process of manufacture may be shown by shells with the outer whorls broken away in steps until the innermost solid

[1]Native copper occurs in the New Jersey trap ridges within a few miles of New York City, an important source in Colonial times being near Boundbrook, 30 miles from the lower end of Manhattan Island. Bowlders of native copper occur in the glacial drift.

column is reached, ground and polished at the end, and needing only cutting off into sections and perforations to make the finished white wampum bead. These do not occur on all sites, though they have been found here and there throughout the region. Ninety-six conch shells with the outer whorls broken entirely away were found in a grave at Burial Ridge, Tottenville, Staten Island, about the head and neck of a skeleton.

Pendants. Occasionally oyster and clam shells, found unworked save for perforations in them, may have been pendants or ornaments, but certainly have little æsthetic value.

Scrapers. Clam shells seem to have been used as scrapers and some are occasionally found with one edge showing the effect of rubbing and wearing. These are rare, however. Some may have been pottery smoothers. Clam shells have been reported which contained central perforations and were identical in appearance with some shell pottery scrapers and smoothers collected by Mr. M. R. Harrington among the Catawba. Contemporary writers mention the use of knives made of shell.

Pottery Tempering. This was sometimes done with calcined and pounded shells, but was uncommon, considering the abundance of the material at hand. Pounded stone or gravel seems to have been more favored.

Pottery Stamps. The corrugated edge of a scallop shell was frequently used as a stamp for pottery, as may be seen by examining the potsherds from this region.

Articles of Bone and Antler.

Objects of bone and antler, while perhaps more abundant here than in New England, are far less plentiful in form and number than in the Iroquoian area. Cut bones are frequent in most shell pits and heaps. They were cut probably with a flint knife, by grooving the bone partly through on all sides, and breaking.

Bone Awls. These utensils are the most common of all bone articles in this region and are found in almost every part of the area. Some are merely sharpened slivers, but others show a considerable degree of work, and are well finished and polished. They are usually made of deer or other mammal bone, but sometimes from the leg bones of birds.

In some instances, the joint of the bone is left for a handle, but this is often cut off. Grooved, perforated, or decorated bone awls are extremely rare in this region. While it is generally considered that these bone tools

were used as awls in sewing leather, as by modern shoemakers, nevertheless, they may have served as forks in removing hot morsels from the pot or for a number of other purposes. The latter supposition is supported by the abundance of bone awls found in some shell pits. The Eastern Cree of the Hudson Bay region use a similar bone implement as the catching or striking pin in the cup-and-ball game.

Bone Needles. These are rare, but found in most localities. They are generally made of the curved ribs of mammals and are six or eight inches long, or even longer. They are generally broken across the eye, which is usually midway between the ends. A few with the perforation at one end have been reported.

Bone Arrow Points, usually hollow and conical in shape, have been found, especially at Tottenville, Staten Island, in the Burial Ridge. They are rather rare, but this may be due to the fact that conditions are not suitable for their preservation in most localities. Others are flat and triangular in shape.

Harpoons. No actual barbed bone harpoons, such as occur in the Iroquois country, have been reported from this region; although the writer has seen what appeared to be part of one from Shinnecock Hills, Long Island, whence comes a harpoon barb of bone found by the writer, now in the Museum collection, which was apparently made to tie to a wooden shaft. While neither of these forms seems to occur within this region, several naturally barbed spines from the tail of the sting-ray, found on the Bowman's Brook site, at Mariner's Harbor, Staten Island, may have been used as harpoons or fish spears, for which purpose they were admirably suited by nature. Long, narrow, chipped stone arrowheads are generally called "fish points" but they do not seem peculiarly adapted for this purpose and the name is probably a misnomer. No bone fish hooks are reported from hereabouts, though suggested by early writers.

Bone Beads and Tubes. While so abundant on Iroquoian sites, tubes and beads made of hollow bird or other animal bones, polished and cut in sections, are very rare here.

Draw Shaves, or Beaming Tools, made of bone, and probably used for removing the hair from skins, were made by splitting the bone of a deer's leg, leaving a sharp blade in the middle with the joints on either end as handles. The writer has seen none from this immediate region, but they are reported by Mr. M. R. Harrington. A number were obtained for the Museum by Mr. Ernest Volk in the Lenapé sites near Trenton, New Jersey. An implement, evidently made of the scapula of a deer, and perhaps used as

a scraper, was found in a grave at Burial Ridge, Tottenville, Staten Island, by Mr. George H. Pepper.

Worked Teeth. Perforated teeth of the bear, wolf, and other animals, so abundant on Iroquoian sites, never seem to be found here. Beavers' teeth cut and ground to an edge, occur, and may have been used as chisels, or primitive crooked knives, or both, as they were till recently by some of the eastern Canadian Algonkian. Other cut beaver teeth may have served as dice or counters in gaming.

Turtle Shell Cups. These are common, and consist merely of the bony carapace of the box turtle (*Terrapene carolina*), scraped and cleaned inside, the ribs being cut away from the covering to finish the utensil for use.

Antler Implements. Deer antlers and fragments of antler, worked and unworked, occur in all shell-heaps and pits. When whole antlers are found, they usually show at the base the marks of the axe or other implement used to detach them from the skull. Cut antler prongs, prongs broken from the main shaft and others partly hollowed and sharpened show the process of manufacture of antler arrow points. These are characteristic of this area and are usually conical in shape, hollowed to receive the shaft, and with one or more barbs; not infrequently, however, they are diamond-shaped in cross-section. The shaft fitted into the hollow socket as in the case of the conical bone arrow points. A large number were found in and among the bones of human skeletons in a grave at the Burial Ridge, Tottenville, Staten Island.

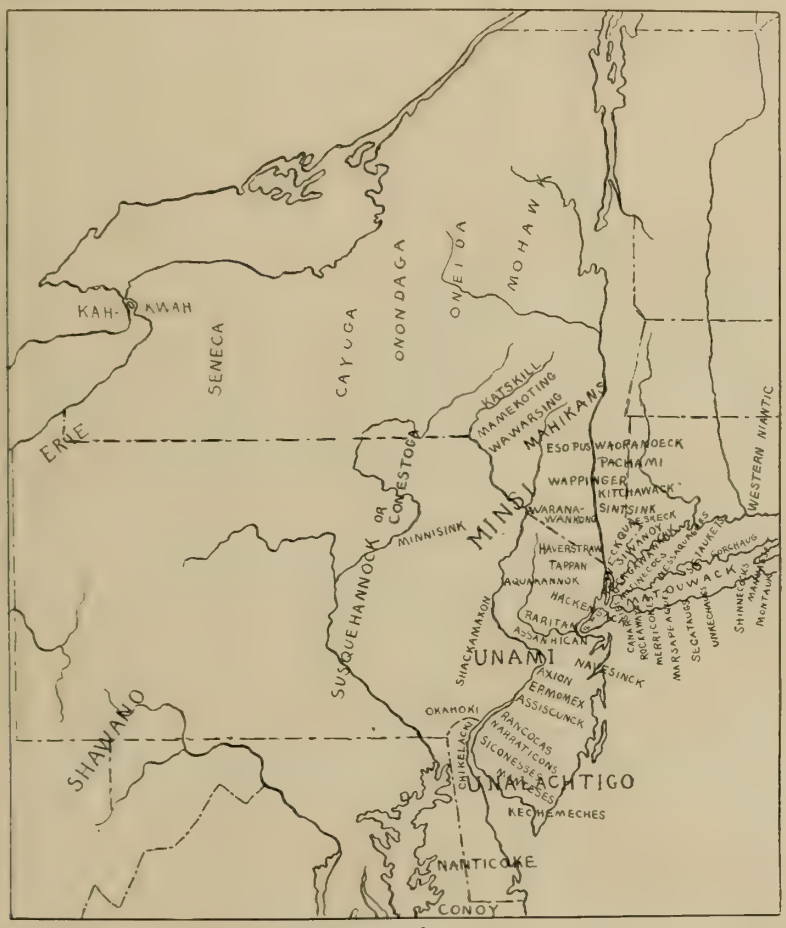
Cylinders, neatly cut and worked all over, or cylindrical tines made of deer antler cut and rounded only at the ends, are not infrequent, and were probably used as flaking tools in making and finishing arrow points by pressure. One broken cylinder or pin, found on the Bowman's Brook site, Mariner's Harbor, Staten Island, had a rounded, neatly carved head. This specimen, however, seems to be unique.

Pottery Stamps, perhaps of antler or bone but which may be of wood, seem to have been used, judging by the decorations of many pottery sherds. A pottery stamp, carved from antler, was found slightly east of this region, at Dosoris, Glen Cove, Long Island, by Mr. M. R. Harrington, and is now in the Museum collection.

Trade Articles.

In spite of the frequent mention by old writers of barter of European for Indian goods, the amount of trade material found is small indeed. While it is abundant in the Iroquoian area, all that has ever been found

here consists of a few round-socketed iron tomahawks, iron hoes, brass or copper arrow points of various styles, a little porcelain, a few glass beads, Venetian and plain, and some old pipes, notably those stamped "R. Tippet" on the bowl. All these articles are very rare here, and for this no adequate explanation can be given.



RÉSUMÉ.

The area treated in this paper was inhabited during historic times by the following tribes:[1]

[1]On the map above, these tribes are shown together with the Long Island and other neighboring tribes as indicated by Beauchamp in the map accompanying his "Aboriginal Occupation of New York," New York State Museum, Bulletin 32, Albany, 1900.

A. The Lenni Lenapé, or Delaware, ranging from the Raritan River, including Staten Island, to Saugerties on the west bank of the Hudson.

Raritan or Assanhican.
Hackensack.
Tappan.
Aquakanonk.
Haverstraw.
Waranawankong.

B. The Wappinger Confederacy ranging along the east bank of the Hudson, eastward to Connecticut, from Manhattan Island.

Rechgawawank or Manhattan.
Siwanoy.
Weckquaskeck.
Wappinger.

C. Montauk or Matouwack Confederacy.
Canarsie.

These tribes were surrounded on all sides by neighbors of the same stock, who differed somewhat in their language and culture. On the south and west lay the Lenni Lenapé, or Delaware proper, on the north the Mahikan, and on the east the New England tribes. Almost without exception, these natives were displaced early in the history of this country, and have been long since expatriated or exterminated. A very few mixed bloods may yet be found on Staten Island, Long Island, and in Westchester County, but their percentage of Indian blood is extremely low.

The remains of aboriginal life now to be found consist of shell-heaps, occurring at every convenient point along the coast, on the rivers, and, more rarely, inland; shell, refuse, and fire pits; camp, village, and burial sites; and rock and cave shelters. With one prominent exception,[1] few or no relics have been found in graves. The typical interment was of the flexed variety. Bone burials, also are not infrequent.

Dog skeletons, complete and intact, bearing the appearance of having been laid out, are sometimes found buried in separate graves. Some writers have supposed that these individual dog burials are the remains of "white dog feasts" or kindred practices, because the Iroquois even up to the present day hold such ceremonies. The white dog is entirely cremated by the Iroquois, and so far as we have been able to find out, there is no record of

[1]Burial Ridge, Tottenville, Staten Island.

such occurrences among the Coastal Algonkin; hence, there seems no reason to attribute this custom to them since other Iroquois traits were so infrequent. It seems more probable that such burials are simply those of pet animals, interred as we today honor a faithful dog.

Some of these dog burials may have been sacrifices made to the Underneath Powers, such as horned snakes, just as is the practice of the western Indians today.

In Waessenaer's *Historie Von Europe*, we read of the Mahikan who lived on the Upper Hudson.

> It appears that the *Sickanamers* before-mentioned, make a sort of sacrifice. They have a hole in a hill in which they place a kettle full of all sorts of articles that they have, either by them, or procured. When there is a great quantity collected a snake comes in, then they all depart, and the Manittou, that is the Devil, comes in the night and takes the kettle away, according to the statement of the *Koutsinacka,* or Devil hunter, who presides over the ceremony.[1]

* * * * * * *

Our Indians may well have sacrificed dogs and buried them for the mythical snake monsters.

Occasionally, the skeletons of dogs and rarely of other animals have been found in graves associated with human bones. The finding of arrowheads among the ribs of some of these, and other circumstances, seem to point to a practice of killing a favorite animal on the death of its owner to accompany or protect the spirit of its master on the journey to the hereafter.

From their appearance and position, many graves seem to indicate that the dead may sometimes have been buried under the lodge, expecially in winter, when the ground outside was frozen too hard to permit grave digging. Others under the same circumstances seem to have been buried in refuse pits. The remains further indicate that "feasts of the dead" were also held at the time of the interment, judging by the quantity of oyster shells and animal bones in and near the graves. Some graves have rows or layers of oyster shells, with the sharp cutting edge upward, placed above the bodies as if to prevent wild animals from disinterring and devouring the dead.

An interesting fact, brought to light by the rock-shelter work of Messrs. Schrabisch and Harrington in their explorations in New Jersey and in Westchester County, New York is that in the lowest and oldest refuse layers of some of these shelters pottery does not occur. It would be ill advised to

[1]Documentary History of New York, Vol. III, p. 46.

infer from this that the earliest occupants were peoples of another culture from the surrounding village dwellers, as the other artifacts found are quite similar to the implements of the latter. Many reasons for this lack of pottery, such as the more easy transportation of vessels of bark or wood through the mountains and hills, suggest themselves, though they are more or less nullified by the presence of pottery in the upper layers. The upper layer, however, may have been made during the period when the natives were being displaced by Europeans and at the same time subjected to Iroquoian raids, when the villages would naturally be abandoned from time to time, for refuge among the cliffs and caves of the mountain fastnesses.

It has been suggested that the rock and cave shelters are remains of an older occupation by people with or without the same culture as the later known savages. The nature of the finds does not support this view, for the specimens obtained are often of as good workmanship as the best to be found in the villages and cemeteries of the latter, while pottery, on the other hand, occurs on the oldest known Algonkian sites. It seems most probable to the writer that, like the shell-heaps, the rock and cave shelters form but a component part, or phase, of the local culture, perhaps a little specialized from usage and environment, but contemporary with the villages, shell-heaps, and cemeteries of the lowlands.

Mounds and earthworks do not occur in the region under consideration, nor does it appear that most of the Indian villages here were fortified, unless they were slightly stockaded. A number of instances of this are known historically, however, and a few earthworks occur just beyond this area[1].

The remains found do not bear any appearance of very great geological antiquity. In a few instances, rock-shelters, shell-heaps, and village sites seem to possess a relative antiquity; but the oldest known remains, in every case, may be placed as Algonkian with considerable certainty. No paleoliths have been reported, and it would seem from the comparative lack of antiquity of the remains that the natives could not have lived in this region for many centuries before the advent of the whites. The accounts of contemporary writers prove conclusively that these archæological remains, if not those left by Indians found here by the early Dutch and English settlers, must have been from people of very similar culture. In culture, the local Indians were not as high as the Iroquois, nor perhaps as the Lenapé or Delaware proper to whom they are related; but they compare very favorably with the New

[1]An earthwork at Croton Point on the Hudson has been excavated by Mr. M. R. Harrington of the American Museum.

England tribes. Absence and scarcity of certain artifacts, such as steatite vessels, the long stone pestle, the gouge, adze, and plummet, and the abundance and character of bone and pottery articles show them to have been intermediate in character between the Lenapé on the south and west, and the New England tribes on the east and north; and consultations of the old European contemporaries show that this was the case linquistically as well as culturally. Examination of the remains also shows that the influence of the Lenapé on the west, and of the New England peoples on the east, was most strongly felt near their respective borders. Iroquoian influence was strong, as evinced by the pottery, and there is also documentary evidence to this effect. Finally, as is frequent throughout most of eastern North America, the archæological remains may be definitely placed as belonging to the native Indian tribes who held the country at the time of its discovery or to their immediate ancestors.

ABORIGINAL REMAINS ON MANHATTAN ISLAND[1]

THE first field work done on Manhattan Island is of very recent date. Doubtless many articles of Indian manufacture and evidences of Indian occupation were found as the city grew up from its first settlement at Fort Amsterdam, but of these specimens we have very few records. An arrow point found in the plaster on the wall of a Colonial house was, without doubt, in the hands of some member of the Kortrecht family; and Indian pottery has been found in a hut occupied by Hessian soldiers during the War of Independence. The first specimens to have been preserved, to the knowledge of those now interested in the subject, were found in 1855, and consisted of Indian arrow points discovered in Harlem during excavation for a cellar on Avenue A, between 120th and 121st Streets. Some of these are spoken of by James Riker[2] as being in the author's cabinet. Riker also speaks of shell-heaps near here.[3] The next specimens preserved were found at Kingsbridge Road (now Broadway) and 220th Street in 1886, and are in the John Neafie collection at the Museum. These consist of an arrow point and a few bits of pottery. The next work was begun in 1889 by Mr. W. L.

[1]By James K. Finch, revised by Leslie Spier.
[2]History of Harlem (1881), footnote, p. 137.
[3]Ibid., p. 366.

Calver of this city, and has led to the discovery of much valuable material which has been preserved.[1]

The following account of the work is taken mainly from Mr. Calver's notebook:

In the autumn of the year 1889, while exploring the heights of Bloomingdale (now called Cathedral Heights) for any relics that might have remained from the Battle of Harlem, Mr. Calver discovered one arrow point at 118th Street, east of Ninth Avenue, and immediately afterwards a circular hammerstone. On a later trip to the same locality, he found a small grooved axe or tomahawk. In February, 1890, while hunting for Revolutionary relics in the vicinity of Fort Washington, he made a trip to the northern part of the island in search of British regimental buttons, many of which were said to have been found in that vicinity. There he met an old acquaintance, Mr. John Pearce, a policeman then on duty there, by whom he was introduced to Mr. James McGuey, a youth residing in the vicinity of 198th Street and Kingsbridge Road and, while crossing the orchard at Academy Street and Seaman Avenue, Mr. Calver saw that the ground was thickly strewn with shells which afterwards proved to be of Indian origin.

The first Sunday in March, Messrs. Calver and McGuey explored this part of the Island for Indian remains. At the junction of Academy Street and Prescott Avenue, they found an Indian potsherd, the importance of which Mr. McGuey seemed to realize, for, a week later, Mr. Calver met him again and was presented by him with a number of fragments of Indian ware. He assured Mr. Calver that he had found them by digging in an Indian graveyard. The two men dug again at this place, and found more pottery. They then went to Cold Spring, a point on the extreme northern end of the Island, and in a shell-heap there they found more Indian work. Mr. Alexander C. Chenoweth, an engineer then on the Croton Aqueduct, hearing of these discoveries, obtained a permit from the property owners and began to explore "The Knoll" at Dyckman Street and Broadway, for Indian remains. After having finished here, he went to Cold Spring and made some further discoveries. All his specimens were purchased in 1894 by the Museum, and some of them are now on exhibition.

[1]In the Spring of 1890 Mr. Edward Hagaman Hall began his investigations and at about the same time Mr. Reginald Pelham Bolton entered the field of local research. In many instances these gentlemen and Mr. W. L. Calver collaborated with valuable results. In the preservation of the traces of Indian occupation of Manhattan Island the American Scenic and Historic Preservation Society (formed in 1899 under the presidency of the late Hon. Andrew H. Green, but now under that of Dr. George Frederick Kunz) has done much pioneer work.

Since this time, several interesting relics have been found, and as the work of grading streets and other excavation at this part of the Island are carried on, more relics will probably come to light.

The only Indian remains left on the Island, so far as known to the writer, are situated at the extreme northern end at Inwood and Cold Spring. They consist of the so-called shell-heaps or refuse piles from Indian camps, and three rock-shelters at Cold spring. But we have evidence to show that this was not the only part of the Island occupied by the Indians. Mrs. Lamb[1] says that the Dutch found a large shell-heap on the west shore of Fresh Water Pond, a small pond, mostly swamp, which was bounded by the present Bowery, Elm, Canal, and Pearl Streets, and which they named from this circumstance Kalch-Hook. In course of time, this was abbreviated to Kalch or Collect and was applied to the pond itself.[2] This shell-heap must have been the accumulation of quite a village, for Mrs. Jno. K. Van Rensselaer[3] speaks of a castle called Catiemuts overlooking a small pond near Canal Street, and says that the neighborhood was called Shell Point. Hemstreet refers to the same castle as being on a hill "close by the present Chatham Square," and says that it had once been an "Indian lookout."[4] Excavations at Pearl Street are said to have reached old shell banks. "The Memorial History of New York"[5] says that a hill near Chatham Square was called Warpoes, which meant literally a "small hill."[6] According to the same authority, "Corlear's Hoeck was called Naigianac, literally, 'sandlands.' It may, however, have been the name of the Indian village which stood there, and was in temporary occupation." This is the only reference we have to this village, but there are references to another on the lower end of the Island. Janvier[7] says that there was an Indian settlement as late as 1661 at Sappokanican near the present Gansevoort Market. According to Judge Benson,[8] Sappokanican ("tobacco field")[9] was the Indian name for the point afterwards known as Greenwich. "In the Dutch

[1]History of New York City, p. 36.

[2]Mr. Edward Hagaman Hall, however, derives the name from "Kolk" or "Kolch," a word still in use in Holland and applied to portions of a canal or inclosure of water.—Editor.

[3]Goede-Vrouw of Manhattan, p. 39.

[4]Hemstreet, Nooks and Corners of Old New York, p. 46.

[5]Bulletin, N. Y. State Museum, Vol. 7, No. 32, p. 107, Feb., 1900.

[6]James G. Wilson, op. cit., p. 52.

[7]Evolution of New York.

[8]N. Y. Historical Society Collections, S. II, Vol. II, Pt. I, p. 84, 1848

[9]All Hilse translations are doubtful.

records references are made to the Indian village of Sappokanican; and this name * * * was applied for more than a century to the region which came to be known as Greenwich in the later, English, times. The Indian village probably was near the site of the present Gansevoort Market; but the name seems to have been applied to the whole region lying between the North River and the stream called the Manetta Water or Bestavaar's Kill."[1] Benton says that the name of the village was Lapinican.[2] Going back to the old Dutch records might lead to finding the actual names and other data regarding these places.

Most of the specimens found on Manhattan Island, as already stated, come from the northern part. We have a few from the central portion, however. There are the arrow-heads spoken of by Riker, and in the Webster Free Library there is a fine specimen of a grooved stone axe found at 77th Street and Avenue B. Mr. Calver has found an arrow-head at 81st Street and Hudson River and specimens from the site of Columbia College have been recorded.

Doubtless the northern part of the Island was inhabited for the longer period; but it is probable that all along the shore, wherever one of the many springs or small brooks, shown on old maps, emptied into the Hudson or East River, there were small, temporary Indian camps. It is likely that these camps were used only in summer, while the primitive occupants of Manhattan retreated to the more protected part of the Island, as at Inwood and Cold Spring, during the winter. Or it may be possible that, as Ruttenber[3] states, the villages on Manhattan Island were only occupied when the Indians were on hunting and fishing excursions, while their permanent villages were on the mainland. Bolton,[4] however, says their principal settlement was on Manhattan Island.

Fort Washington Point. There is a small deposit of shells on the southern edge of the point, in which the writer found some small pieces of pottery and a few flint chips, thus proving its Indian origin. This was probably a summer camp, as it was too exposed for winter use.

Zerren ner's Farm. A favorable sloping field at 194th Street and Broadway now used for truck farming, was utilized as a camp site. Camp débris of varied character has been plowed up here. Perhaps the overhanging

[1]Thos. A. Janvier, in Old New York, pp. 85-86.
[2]New York, p. 26.
[3]Indian Tribes of Hudson's River, p. 78.
[4]History of Westchester County, p. 25.

rocks below Ft. Washington, between 194th and 198th Streets on Bennett Avenue, afforded the Indians some shelter in winter.

Inwood Station Site. At the foot of Dyckman Street and Hudson River, there existed a large deposit of shells, most of which were removed when the rocks on which they lay were blasted away for grading the street. A few arrow points and bits of pottery, as well as several Revolutionary objects, were found here. There are photographs of this deposit in the Museum.

Seaman Avenue Site. This site, between Academy and Hawthorne Streets, running through from Seaman Avenue to Cooper Street, is the most extensive village site from which remains have been collected. It was a British camp site during the Revolution, and a number of buttons, gun-flints, and bullets have been found there, as well as numerous Indian remains. It seems to have been the workshop for a red jasper-like stone of which numerous chips but no finished implements have been found. The shells at this point were first noticed by Mr. Calver in 1890. They may not all be of Indian origin, as some may be due to Revolutionary soldiers.

Harlem River Deposit. Mr. Calver says, "Extending from 209th Street to 211th Street on the west bank of the Harlem River and almost on a line with Ninth Avenue was another large deposit of oyster shells lying just beneath the top soil of the field. These shells had nearly all been disturbed by the plow and were interesting only for their color, which was red. Pieces of horn of deer and split bones of the same animal were common among the shells; but, in spite of the apparent antiquity of the deposit, there were, even in the lowest strata of it, some small fragments of glass, which proved that either the whole mass had been disturbed or else the shells had been left during the historic period." There are several stone sinkers and hammerstones from this spot in Mr. Calver's collection and at the Museum.

Isham Park Site. On the knolls along the south side of Isham Park, and particularly in Isham's Garden, about on the line of Isham Street and Seaman Avenue, the soil is white with small fragments of shells. A number of arrow points, flint chips, hammerstones, sinkers, and potsherds have been found here. On the knolls to the south of this garden, an Indian burial, shell pockets with small deposits of pottery, etc., and several dog burials, have been found. There are two small shell-heaps, containing chips and potsherds, in the Park on the bank of the Ship Canal, and several shell pockets were disturbed in excavating 218th Street on the north side of the Park.

Cold Spring. Cold Spring is situated at the extreme northern end of Manhattan Island on the southern shore of Spuyten Duyvil Creek. The Indian remains consist of three rock-shelters and three refuse heaps. The rock-shelter is a formation where the overhanging rocks form a small cave or shelter which the Indians used as a dwelling place. All their rubbish, such as oyster shells, broken pottery, and broken arrow-heads, were dumped near by, forming the so-called shell-heaps. Messrs. Calver and McGuey explored the shell-heaps; but Mr. Chenoweth was the first to suspect the existence of the shelters. There is only one which is likely to have been used as a dwelling place, the others being places where food was stored or shelters for fires used in cooking. These shelters face east, and are at the foot of Inwood Hill (formerly called Cock Hill), which forms the most northern part of Manhattan Island. The largest one was formed by several of the rocks breaking off the cliffs above and falling in such a manner that, by digging out some of the earth from beneath them, the Indians could make a small shelter. Probably it was occupied by one family, while the others lived in bark wigwams near by.[1] Another of the shelters is simply an excavation under the end of a huge fragment which also dropped from the cliffs above, and the third is a large crevice in the foot of these cliffs. When Mr. Chenoweth first explored them, all these shelters were completely filled with earth which had gradually worked its way in since their occupation, and much credit is due him for suspecting their presence. In them he found fragments of pottery and stone implements, together with the bones of turkey and deer. The largest of the refuse heaps is situated on a rise directly in front of the shelters. It consists of a layer of shells, in places one foot thick, found under a layer of fine loam, a black earth which has been deposited since the shells were scattered over the original sandy yellow soil. The sheltered position of this place made it an especially desirable camp site. The hills to the south and west formed a protection to the camp from winds, and by Spuyten Duyvil Creek access could be had to either Hudson or East River; while the Cold Spring, from which the place takes its name, furnished an abundant supply of fresh water.

Harlem Ship Canal. Formerly at 220th Street and Kingsbridge Road was a large deposit of shells on the westerly side of the road. This was destroyed when the ship canal was put through. As with the Inwood Station site, no systematic examination of this place was ever made. Mr. John Neafie found some potsherds here in 1886. Mr. Chenoweth also has

[1]Memorial History of New York, Vol. I, p. 33, for picture of houses, and p. 30 for description.

some potsherds from here.[1] Mr. Calver says that this was a large deposit, and that the peculiar thing about it was that the shells were so wedged and packed together that a pick would hardly penetrate them. They lay on the bare rock surface in cracks in the rock; a condition common to this neighborhood.

Shell Pockets at 211th Street. In March, 1903, there was considerable excitement over the reported discovery of an Indian graveyard at 211th Street.[2] The graveyard proved to have been that of some slaves, and was situated on the western end of the rise between 210th and 211th Streets, on the eastern end of which is the old Neagle Burying Ground. This discovery was interesting because under the Negro graves several shell pockets of undoubted Indian origin came to light. The workmen, in grading Tenth Avenue, cut into this hill to obtain material for filling, and uncovered the graves and pockets. It seems almost certain that the deposits were made some time ago; then the wind blew the sand over the deposits to a depth of four or five feet, and Negroes later used this place as a burial ground. In support of this theory is the fact that the pockets were four or five feet under the surface, that the soil above showed no signs of having been disturbed, and that this rise is put down on the Government maps of this section as a sand dune.[3] During the summer of 1904, Mr. Calver with Messrs. Hall and Bolton uncovered nine or more pockets to the southwest of the graveyard.[4] These pockets all seem to have been of the same period as the others, and all appear to have been on the original ground surface, although those farther up the hill were some four feet under the present surface. In one of these pockets was found the complete skeleton of a dog,[5] in another, a turtle shell; two others contained complete snake skeletons; while a fifth held the fragments of a small pottery vessel. The pockets were small, being about three feet in diameter and of equal depth, showing no signs of having first been used as fireplaces and then filled up, though charcoal was scattered among the shells. Almost all the relics from Van Corlandt Park were found by Mr. James in pockets similar to these.

During Indian troubles in 1675, the Wickquaskeek at Ann's Hook, now Pelham Neck, were told "to remove within a fortnight to their usual winter

[1]John Neafie collection, 20-2558; Chenoweth, 20-3498.

[2]Evening Telegram, March 14, 1903.

[3]New York Geologic Folio.

[4]New York Tribune, Oct. 30, 1904, and New York Sun, Dec. 14, 1904.

[5]All that could be saved of this skeleton has been presented to the Museum by Mr. Edward Hagaman Hall.

quarters within Hellgate upon this Island." River says, "This winter retreat was either the woodlands between Harlem Plains and Kingsbridge, at that date still claimed by these Indians as hunting grounds, or Rechawanes and adjoining lands on the Bay of Hellgate, as the words 'within Hellgate' would strictly mean, and which, by the immense shellbeds found there formerly, is proved to have been a favorite Indian resort."[1] A little later the Indians asked to be allowed to return to their maize lands on Manhattan Island and the Governor said that they, "if they desire it, be admitted with their wives and children, to plant upon this Island, but nowhere else, if they remove; and that it be upon the north point of the Island near Spuyten Duyvel."[2]

Mrs. Mary A. Bolton Post, in writing to the editor of "The Evening Post," June 19th of the year of the opening of the Harlem Ship Canal (1895), speaks of some Indians who were allowed to camp on the south side of Spuyten Duyvil Creek on the Bolton property in 1817. Ruttenber says that the Reckgawanc had their principal village at Yonkers, but that on Berrian's Neck (Spuyten Duyvil Hill) was situated their castle or fort called Nipinichsen. This fort was protected by a strong stockade and commanded the romantic scenery of the Papirinimen, or Spuyten Duyvil Creek, and the Mahicanituk (Hudson River), the junction of which as called the Shorackappock. It was from this castle that the Indians came who attacked Hudson on his return down the river.[3] Some small shell deposits occur on Spuyten Duyvil Hill, but as yet this "castile" has not been definitely located. The village site at Yonkers, according to Mr. James, is now covered by buildings; but several relics found near the site years ago are now in the Manor Hall at that place (1904).

Judging from these references, we might conclude that the territory occupied by the tribe commonly known as Manhattan included Manhattan Island and that part of the mainland which is west of the Bronx River south of Yonkers, and that these Indians were a sub-tribe of the Wappinger division of the Mahikan.

Notable Types of Remains.

Dog Burials. The first dog burials were found by Mr. Calver in 1895. The first burial was unearthed at the summit of a ridge of soft earth at 209th Street, near the Harlem River. The ridge, which was about twelve feet

[1]History of Harlem, p. 366.
[2]History of Harlem, p. 369.
[3]Ruttenber, pp. 77-78.

high, had been partly cut away for the grading of Ninth Avenue. It was at the highest part of the hillock that a pocket of oyster and clam shells was noticed, from which a few fragments of Indian pottery which lay on the face of the bank had evidently fallen. The shells, upon inspection, were found to have served as a covering for the skeleton of a dog or wolf. Another burial was found on May 18th within fifty yards of the first burial. It had been covered with shells just as the first one, but had been distributed by workmen. Mr. Calver says: "The two canine burials were situated at a point just without the borders of the Harlem River shell-heap and were distinct from it. The shells were found to be matched, hence it was concluded that they were thrown in unopened or eaten on the spot. As the skeletons were intact and the bones uninjured, all probability of the animals having been eaten is disposed of." These burials are common in this vicinity; Mr. Calver thinks they were for some religious purpose, and suggests a relation to the "White Dog Feast" of the Onondaga of this state.[1] However, it is known that the carcass of the sacrificed dog was burnt by the Iroquois and the explanation given on page 46 is probably correct.

Indian Burials. Notwithstanding all the efforts of various collectors, the first Indian burials to be discovered on the Island were due to the activities of Messrs. Bolton and Calver in 1904. The improvement of Seaman Avenue, Inwood, at that time, uncovered many relics of the long extinct Indian inhabitants, among which Mr. Bolton saw unmistakable signs of Indian graves. To quote from this gentleman: "It thus became evident that there were human interments in the vicinity, and in August, 1907, the first burial was discovered under a shell pit in Corbett's garden. The grading process had been extended only about eighteen inches below the sod, but had sufficed to destroy the jaw of the skeleton which extended upwards, as did also the foot bones. The bones lay in and upon a close mass of oyster shells, some of which were unopened. The skeleton reclined on its right side, facing west. The arms were flexed and crossed, the knees bent and the head thrown back. No traces of weapons were found, nor were there any other objects found, save a fragment of an animal bone.

"The location and position led to further exploration which early in 1908 led to still more interesting discoveries. Sunday, March 22nd, being the first day in the field for exploration for the season for 1908, W. L. Calver and the writer met at Seaman Avenue and Hawthorne Street, Manhattan, to discuss plans for further excavations on this Indian village site. The rains

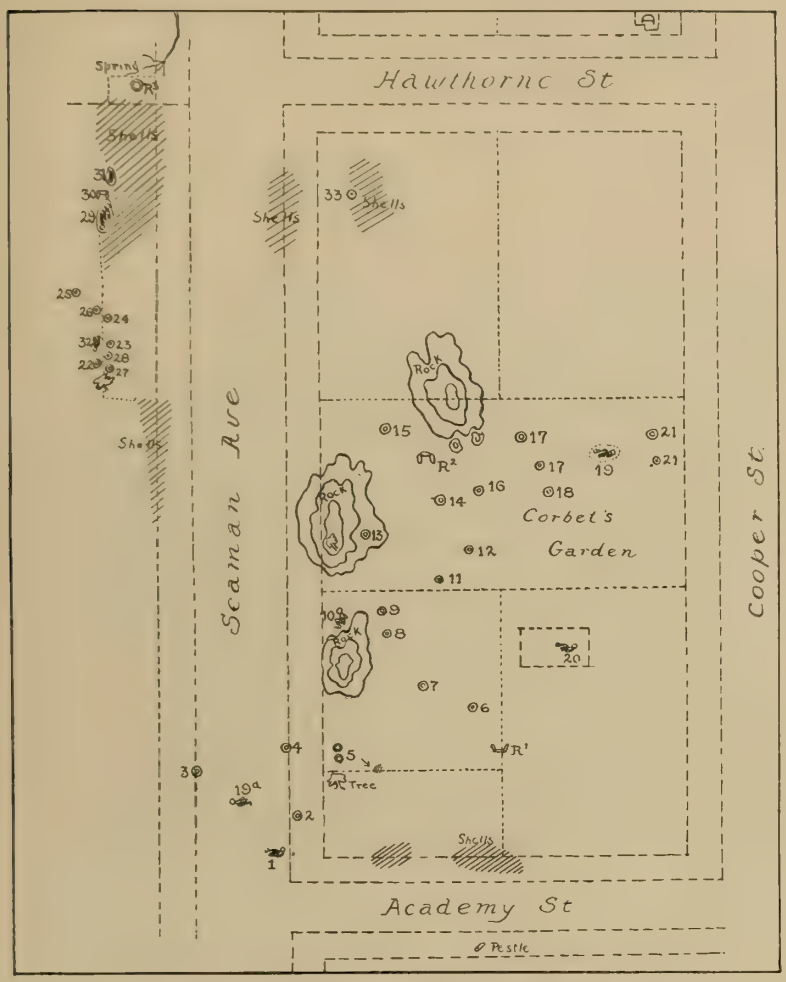
[1]New York Herald, May 26, 1895.

of the winter 1907-8 had washed the west bank where the layer of oyster shells and black dirt lay along the hill, and a patch of red burnt earth was observed, which on digging out, disclosed a fireplace, evidently of the period of the Revolution, having some large burnt stone, ashes, wood charcoal, brick, broken rum bottles, a wine glass nearly complete, a large open clasp-knife with bone handle, a hoop-iron pot-hook, various forged head nails and

INDIAN BURIAL, MANHATTAN

a curious folding cork-screw. Gold buttons of Revolutionary pattern and an officer's silver button of the Royal Marines, together with pewter buttons of the 17th Regiment, disclosed who had occupied the spot.

"At one part of this fire place, we came upon a pocket of oyster shells, evidently Indian, about two feet deep, and on removing some of these, had the good fortune to uncover a human thigh-bone. We worked carefully into the shells and under the pocket, gradually disclosing the complete remains of a full-grown man lying on its right side, feet to the north, head facing east, knees doubled up, the left arm extended down through the thighs. The feet had been within the area of the hole in which the Revolu-



LOCATION OF BURIALS, PITS AND SHELL BEDS NEAR INWOOD

1. Human remains. 2. Shell pit, deer antler. 3. Shell pit. 4. Shell pit, pottery. 5. Shell pits 6. Shell pit, sturgeon below. 7. Shell pit, sturgeon scales. 8, 9. Shell pits. 10. Human remains. 11. Fire pit. 12. Shell pit. 13. Dog burial, puppy. 14. Shell pit. 15. Part of a jar. 16. Shell pit, fish and meat bones. 17. Shell pits. 18. Two dogs in shell pit. 19. Human skeleton, 1907. 19a. Female skeleton, 1908. 20. Human remains when house was built. 21. Small fire pits, Revolutionary. 22. Large shell pit. 23. Large shell pit. 24. Shell pit. 25. Dog burial. 26, 27, 28. Shell pits. 29. Two human skeletons, male and female. 30. Revolutionary fireplace "Royal Marines" and "17th." 31. Skeleton female, and infant. 32. Skeleton (Chenoweth, 1908). 33. Revolutionary fireplace. 71st, officers' buttons. D. Dyckman dwelling. R^1, R^2. Revolutionary fireplaces. R^3. Revolutionary well.

tionary fireplace had been made, and only one or two foot bones were found. At a later period other foot bones were found on the opposite side of the Revolutionary fireplace, evidently having been displaced in its construction. The right arm was flexed, and the hand was under the head, the latter was intact and every tooth was in place. Shells had been packed over the body, and some around it. We were much puzzled by a number of human bones lying compactly together by the skeleton, in a position that would have been in its lap, had it been upright.

"We removed the skull, covered the remains, and on Sunday, March 29th, renewed the work. We went carefully to work upon the cluster of mixed bones in front of the large skeleton, and soon found them to be rather compactly arranged in a rectangular form about 14 by 26 inches, the long bones parallel. The vertebræ ended abruptly parallel with the head of the larger skeleton, and after working some time, we found a skull placed below, beneath the pile of bones in a vertical position, facing north, the lower jaw of which was disengaged, and was placed sideways in front of the face. The back of the skull was broken in, and was black with marks of burning. The lower jaw was burned, and some of the teeth split by fire. The arm and leg bones were charred at the joints. Inside the skull was a burned toe bone. There were some oyster shells among the charred remains.

"A significant fact was that the right arm bones of the large skeleton were below the pile of burned bones. This feature, and the compact arrangement of the latter within the space in front of and at the same level as the large skeleton, seem to point strongly towards an intentional arrangement of these bones, in front of the large corpse and to indicate the simultaneous burial of the two bodies. On examination, the large skeleton proved to be that of an adult male, and the dismembered remains those of a female of about 35 years of age. No implements were found with the remains, but a part of a stone pestle and a rude celt lay under the sod among the oysters above the large skeleton.

"On Sunday, June 14, 1908, another burial was found about 20 feet north of the above. This burial consisted of an adult skeleton doubled up and its back much curved, and was apparently that of a female of mature age. Between the knees, the remains of a small infant were laid, the skull of the latter being fragmentary. The right hand of the adult was below the infant and the left hand around the throat. The skull was intact and had nearly all the teeth. One finger bone had grown together at the joint in a crooked position apparently due to disease. On lifting the ribs of the right side, an arrow-head of flint fell out between the fourth and fifth

bones. These skeletons lay about two and a half feet below the grass, and a pocket of oyster shells was over the heads. The woman's remains lay within a space about 31 inches long by 50 inches wide, flat in the hard red sand bed facing east.

"Shortly after these remains were discovered, Mr Chenoweth extended the excavation previously made by the explorers at the side of a large oyster shell pit in the same bank of sand, and uncovered a male skeleton of which he preserved the skull. Some small fragments of the skeleton were afterwards found by the writer on this spot. Contractors for the sewer in Seaman Avenue also uncovered the remains of a young female close to the position of several of the shell pits previously described. These interments have some curious features. The position of the remains facing east, sometimes west, the absence of weapons or other objects and the oyster shells packed with or above them are subjects for interesting discussion on which future finds may throw much light, as also upon the peculiar double burial and the burnt state of the female remains."

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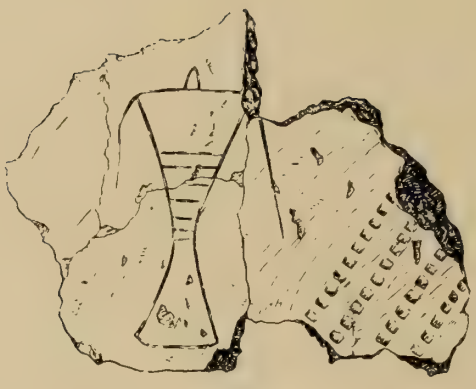


THE THUNDERBIRD

Engraved on a fragment of pottery found at Shinnecock Hills, Long Island. The thunderbirds were gods and patrons or warriors and it is one of their duties to guard mankind from the evil horned serpents (page 10) that dwell under the earth or beneath the waters.

Man and Nature

PUBLICATIONS

Science Guide No. 41

THE AMERICAN MUSEUM OF NATURAL HISTORY

THE BIG TREE AND ITS STORY

By GEORGE H. SHERWOOD

GUIDE LEAFLET No. 42

FIFTH EDITION DECEMBER, 1929

AMERICAN·MUSEUM·PRESS

THE BIG TREE AND ITS STORY

The Sequoia and the History of Biological Science

By GEORGE H. SHERWOOD

The American Museum of Natural History
Guide Leaflet No. 42
Fifth Edition, New York, December, 1929

THE BIG TREE AND ITS STORY

The Sequoia and the History of Biological Science[1]

The Story of the Big Tree as briefly told on the label

This Big Tree lived nearly 1400 years. It sprouted in its undiscovered mountain wilderness of the New World some 500 years after the time of Christ when the Roman Empire had only just come to an end. It witnessed the birth of Mahomet and was a good-sized tree in the reign of Alfred the Great. It was not far from 1000 years old at the time America was discovered. Three hundred and fifty years later when the pioneer life of America had spread from the eastern shores to the western and the lofty race of the sequoias had been found by civilized man in (1853), this tree was 1300 years old. It had thus held its crown steadfastly to the sky while some forty generations of men lived and died.

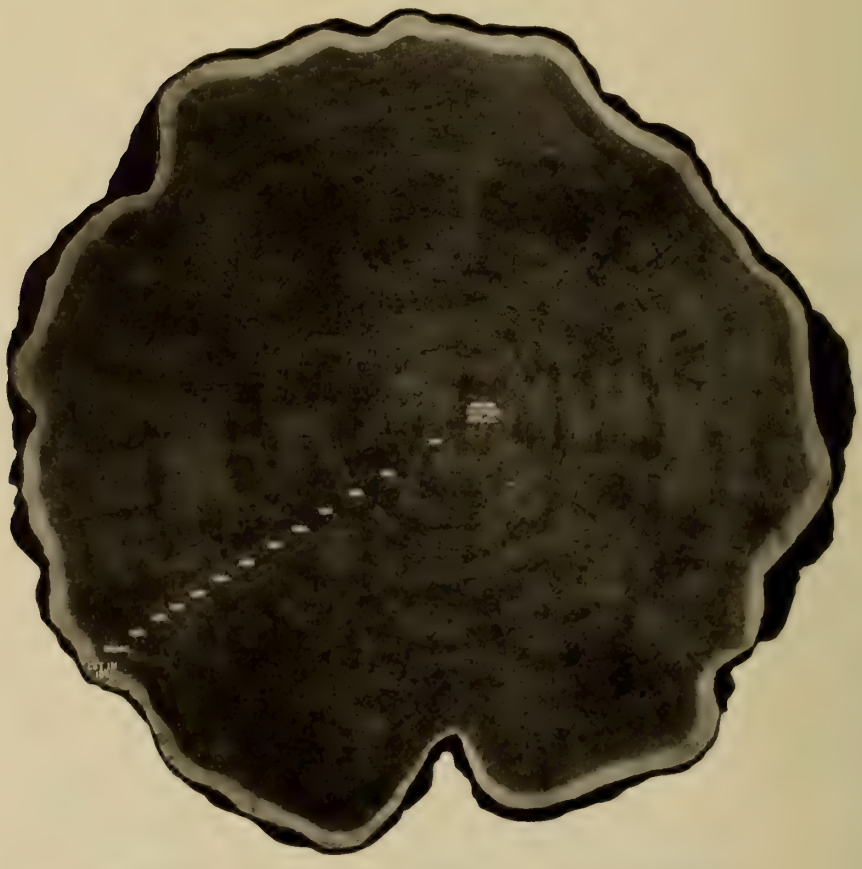
A Big Tree may live 5000 years, however, and perhaps longer if not destroyed by accident or disastrous climatic change. Those Big Trees of California averaging from 2000 to 3000 years old have lived no more than half, possibly only a fraction, of the time they might live. If they now escape fire and the ax, they are likely to continue to look down on the world for still other thousands of years, while some hundred more generations of men are born and die, while present weakened civilizations decline and others better founded triumph.

Moreover, as the centuries go on, these trees will seem increasingly remarkable, for not only are they god-like among trees in stature and length of life, but also they are as strangely out of place among the world's other trees as would be the mastodon and mammoth among our deer and oxen. They belong to an old race which flourished, especially in the Arctic regions, during Tertiary and Cretaceous times and was destroyed by the coming of the Glacial Period. But the destruction was not quite complete: two species, the Big Tree and the Redwood, on the oldest, warmest parts of California's mountains, succeeded in bridging the time of ice. There to-day—and nowhere else on the globe—the remnant of the ancient race stands. The peculiar distribution in groves separated by wide gaps was probably caused by ancient glaciers which lingered in these gaps.

[1]The greater part of this leaflet was written by George H. Sherwood and appeared in Leaflet No. 8, The Sequoia. Additions and changes have been made by Henry E. Crampton and F. A. Lucas. The label is by Miss M. C. Dickerson.

The section of the Big Tree "Mark Twain," shown below, was given to the Museum by Collis P. Huntington in 1891. It came from the King's River Grove in Fresno County. The section measures 16½ feet in diameter inside the bark and was cut from the tree twelve feet above the ground. It was divided into twelve sections for shipping, and after years of seasoning weighs nine tons.

The section immediately above this was presented to the British Museum by Mr. Huntington.



SECTION OF THE TREE IN THE HALL OF FORESTRY

DISTRIBUTION OF THE BIG TREE

The relative sizes of the groves are indicated by the number of trees on the map.
The shaded portion of the small map shows how limited is the area covered by these trees.

THE SEQUOIA

It is fitting that the entrance to the Hall of Trees of North America should be flanked on either hand by the Redwood and Sequoia. Not only are these the noblest of trees, but they are strictly North American trees and their name perpetuates that of the old Cherokee Chieftain Seequoyah.

It is with the Sequoia, however, that we are concerned, the greatest and probably oldest of living trees, although its claims to antiquity are now and then disputed by some claimant like the Bo-tree or sacred fig of Ceylon, a scion of the tree under which Gautama Buddha sat when he attained Nirvana, which has a recorded history of a little over 2200 years.

Another "oldest inhabitant" is, or was, the great dragon tree of Teneriffe, which, when blown down in 1868, was "estimated" to be 6000 years old. Estimates, are, however, unreliable, and this age is given for what it is worth.

Still another ancient of days, or years, is the cypress of Santa Maria, Tule, Mexico, which, according to Frederick Starr, has a circumference of one hundred and sixty feet, four feet above the ground. It is, however, very irregular in outline and is possibly formed by the union of three trunks.

The Sequoia is not only the oldest of trees, but the mightiest, and while from time to time there have been reports of rivals in Australia, yet these rivals when brought to the ultimate test, that of the tape line, have shrunk before it, leaving the Sequoia the monarch of them all.

The Kauri Pine of New Zealand, so far as size goes, is a really dangerous rival, and two examples are no record having respectively diameters of twenty-four and twenty-two feet, and estimated ages of 1396 and 1280 years.

The following are the measurements of a few of the largest trees in the principal groves; though of little value for comparative purposes, they serve to give an idea of the vast proportions of the Big Trees.

A. Tuolomne Grove, diameter at 3 feet above ground, 23 feet.

B. Fresno Grove, circumference at 3 feet above ground, 81 feet.

C. King's River Grove, circumference near the ground 116 feet, height 276 feet.

D. King's River Grove, diameter (without bark) at 120 feet above ground, 13 feet 2 inches.

E. Calaveras Grove (dead, without bark), diameter at 6 feet above ground, 25 feet, height 302 feet; circumference at ground, 96 feet. .

F. Calaveras Grove (dead, without bark), circumference at base 84 feet, height 321 feet.

G. Calaveras Grove (dead, without bark), diameter at 3 feet above ground, 23 feet 2 inches; height to present top 365 feet (estimated former height 400 feet).

H. Calaveras Grove, diameter at 6 feet above ground 14.3, height 325 feet.

I. Calaveras Grove, diameter at 6 feet above ground 12.7, height 319 feet.

J. Calaveras Grove, diameter at 6 feet above ground 19.4, height 315 feet.

K. Calaveras Grove, diameter at 6 feet above ground 15, height 307 feet.

L. Stanislaus Grove, circumference at base 103 feet, height 311 feet.

M. Mariposa Grove, circumference at base 93.7 feet, circumference at 11 feet, 64.3 feet.

N. Mariposa Grove, diameter at 6 feet, 21.4 feet, height 270 feet.

Curiously enough the decline of the big tree, like that of big states, is possibly due to the fact that it cannot stand prosperity. Shade and rich soil, factors conducive to the reproduction of most trees, are detrimental to the Sequoia; it demands sunlight and sandy soil from which leaf mold has been removed. For this reason there are practically no seedlings in the shadows of the untouched northern groves, but wherever in the southern groves lumbering and fire have opened up the forest and exposed the mineral earth, an abundance of young Big Trees is always found near seed trees, unless, of course, fire has destroyed them. The dependence of this tree for its reproduction on direct sunlight and open soil is particularly evident in the Tule River cañons where very open stands of large Big Trees have invariably seeded up the washed gravelly soil.

It is evident that under favorable soil and light conditions the Big Tree is not lacking in reproductive energy, and that under these conditions it is holding its own in competition with other trees. Although it is but meagrely represented in the few scattered groups now preserved, the species seems still to possess that strong inherent reproductive power that permits survival of the fit.

And yet, seen by itself, the Sequoia is not a particularly fine or beautiful tree; it is too largely trunk. To appreciate its true grandeur it must be seen in company with its fellows, when the eye travels from one massive trunk to another, each towering upwards to be lost in a mist of foliage.

Once spread over a large part of the Ancient World, the Sequoia is now making its last stand on the Sierras of our western coast, where it is confined to a few isolated groves found at altitudes of from 4000 to 8000 feet above the sea. Thirty-one of these groves or groups are now known,

THE STUMP OF "MARK TWAIN"
Ninety feet in circumference

numbering from half a dozen to several thousand trees each, occupying altogether an area of only about fifty square miles. This area is bounded on the north by the American River, and on the south by Deer Creek, and the total distance from the most northerly group (North Grove) to the most southerly (Tule River Grove) is only 260 miles. The King's River and Kaweah River Grove is the largest both as to area and number of trees. The extent of this district is four or five miles in width, and eight or ten miles in length. It has a variation in altitude of 2500 feet. It is an interesting fact that as one proceeds from north to south the Big Trees flourish at higher and higher altitudes.

As might be inferred from its age the Sequoia is tolerant of injuries and its recuperative power great, so that it recovers from damage done by fires, ancient and modern, that have destroyed many other trees. Our own specimen has suffered somewhat, but Professor Dudley recorded one whose troubles date back to 245 A.D., at the age of 516, when a forest fire inflicted a wound it took 105 years to cover. The next 1200 years were years of peace, but in 1441 A.D., at 1712 years of age, the tree was burned a second time in two long grooves one and two feet wide respectively. Each had its own system of repair. 139 years of growth followed, including the time occupied by covering the wounds. 1580 A.D., at 1851 years of age, occurred another fire, causing a burn on the trunk two feet wide, which took 56 years to cover with new tissue. 217 years of growth followed the burn. 1797 A.D., when the tree was 2,068 years old, a tremendous fire attacked it, burning the great scar eighteen feet wide. 103 years, between 1797 and 1900, had enabled the tree to reduce the exposed area of the burn to about fourteen feet in width. It is to be noted that in each of the three older burns there was a thin cavity occupied by the charcoal of the burned surface, but the wounds were finally fully covered and the new tissue above was full, even, continuous and showed no sign of distortion or of the old wound.

The wood yielded by the Big Trees while vast in quantity is rather indifferent as to quality, being light, soft and brittle, though it does possess one good quality, that of durability in contact with the soil.

The methods of lumbering the Big Trees are wasteful in the extreme, more or less of necessity. These huge trees are usually shattered in falling, but when they are not, logs of ten or twenty feet in diameter are a little too large to handle, so the fallen Sequoia is by the use of dynamite reft into pieces large enough to handle, a process that wastes about half the timber in a tree. Still, as Mr. Huntington writes, "3000 fence posts, sufficient to support a wire fence around 8000 or 9000 acres, have been made from one of these giants, and that was only the first step towards using its carcass. 650,000 shingles, enough to cover the roofs of 70 or 80 houses, formed the second item of its product; finally there still re-

TREE SHATTERED IN FALLING

mained hundreds of cords of firewood which no one could use because of the prohibitive cost of hauling the wood out of the mountains."

Thus far the Sequoia in general—our own particular tree which came from the King's River Grove, was felled in 1891 and literally cut off in the 1341st year of its growth. This to be sure is a good old age, as things go nowadays, but Dudley speaks of a tree "of moderate age" that when cut in 1900 had reached an age of 2171 years, and Huntington "counted the rings of 79 that were over 2,000 years of age, of 3 that were over 3,000 and of one that was 3,150," a sturdy sapling at the time of the Exodus.

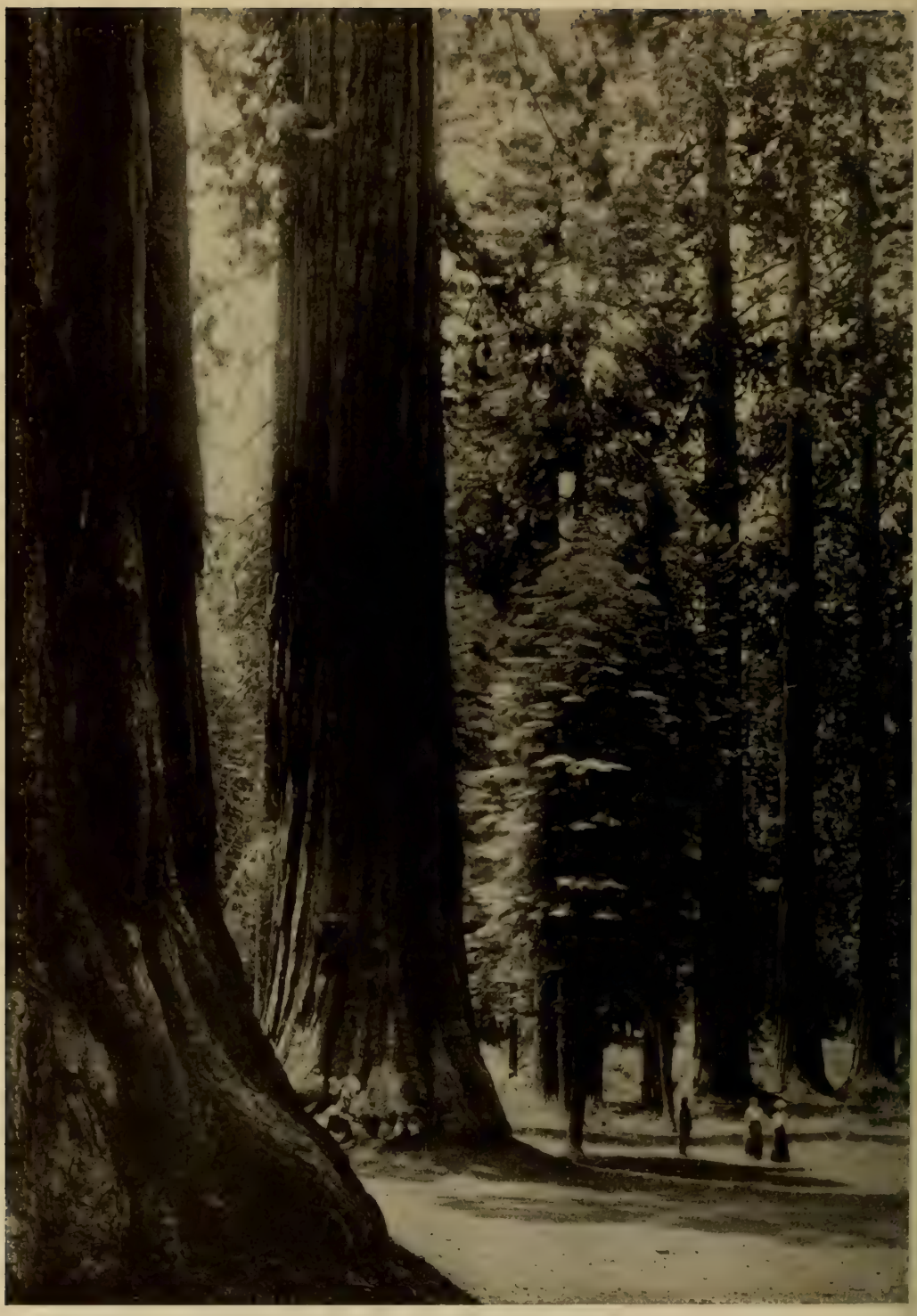
Compared with this, our own tree was in the full vigor of middle life, though it had lived through many of the most eventful periods in the history of the world: the most eventful so far as we are concerned. It witnessed the death of old nations, the birth of new, and might well be considered as ancient when Columbus discovered America and the history of the New World really began. And what progress has this, our Sequoia, seen during its long career! When it began, steel, steam, electricity and all that they make possible, were unknown factors in the progress of civilization. And as for that combination of belief, theory and knowledge of living things that we term biological science, our Sequoia saw all save its birth with the writings of Aristotle. And as this science lay dormant for many years it really saw all worth seeing.

To Professor Ellsworth Huntington belongs the credit of having found a scientific use for the large stumps of the Sequoia. As is well known, in regions where there is a marked difference betwen the climate of summer and winter, whether there be heat and cold or moisture and dryness, the years of a tree's life are marked by rings of annual growth.

Moreover the width of these rings shows whether the year was favorable or unfavorable for growth, a thick ring, for example, indicating a moist season, a thin one a dry year.

Owing to the great age attained by these trees they must have passed through many vicissitudes of climate, and if there have been appreciable changes of climate during a period of a thousand years, they should be recorded in the Sequoia by a succession of wide or narrow rings. So reasoned Professor Huntington.

And this reasoning is borne out by the facts: knowing certain changes that have taken place in the last thousand years or more, indicated by abandoned cities, shrunken lakes and the transformation of fertile plains into deserts, he was able to show what changes had taken place during historic times and fix the dates of long periods of drought. Now by counting the rings of the Big Trees and noting the favorable or unfavorable conditions recorded by them, Professor Huntington was able to show that the records of the Sequoia corresponded with the known facts of history.



VIEW IN MARIPOSA GROVE

"General Grant," "General Sherman" and "The Four Guards"

VIEW IN CALAVERAS GROVE

"Mother of the Forest," in background, 84 feet in circumference

FELLING THE TREE

This method of research has been carried into geologic times, and by observation of the rings on the trunks of fossil trees, it has been possible to obtain an idea of changes of climate that occurred long ages ago.

When the tree was a mere sapling, Europe was overrun by the Goths, Vandals and Franks, and a state of almost universal war prevailed. About twenty years later Mahomet was born and then followed the establishment of the Mohammedan religion, which, during the next one hundred and fifty years, reached the zenith of its power and threatened to overrun the whole world. This Saracenic invasion was checked at the battle of Tours (732), in which the Franks under Charles Martel overwhelmingly defeated the Mohammedans. The beginning of the next century was marked with the crowning of Charlemagne on Christmas day, 800. This monarch made a noble effort to educate his people by establishing a school at his court and inviting thither the few learned men of his time.

The climatic conditions in California during A.D. 800 and the year preceding must have been very favorable for the growth of our tree, which had already attained the size of a large elm. Its growth during these two years, indicated by the large rings, was phenomenal.

During this century occurred also the effort of King Alfred to establish schools in England. The hardy Norsemen began their bold voyages in quest of treasure and adventure, colonized Iceland in 874, discovered Greenland (981), and pushing farther westward probably sailed down along the eastern shore of America.

The Crusades, begun in 1096 and continuing for almost 200 years, brought the various European peoples into intercourse which resulted in exchange of ideas and helped prepare the popular mind for the discoveries which were soon to follow.

The first half of the thirteenth century saw the founding of the universities. First the University of Paris (1200), which became the center of theology; a few years later were founded the University of Bologna, famous for law, and the University of Padua, which attracted the greatest students of medicine. In England, Oxford University was founded in 1249.

The fifteenth century brought those marvelous discoveries which were of so much importance in the advancement of civilization, and which contributed to the growth of science. Printing with wooden block type was introduced by John Gutenberg in 1438, and his invention was followed in 1450 with the use of metal type, making the general dissemination of knowledge possible.

Columbus' discovery of America (1492) was followed by Magellan's famous trip around the world to the westward (1519–1522), during which he discovered the Philippines; and about the same time Cortez

conquered Mexico. The New World was soon explored for its reputed hidden treasures, and astronomers' search of the heavens for an orderly movement of planetary bodies resulted in the elaboration of the system of Copernicus (1543). Kepler announced his laws of planetary motion at about the same time (1609), and in the latter part of the seventeenth century Newton enunciated the law of gravitation. The increasing freedom of thought was expressed in the American and French Revolutions.

The rapid course of invention during the nineteenth century is too familiar to require detailed mention. This period of the tree's growth, however, is represented by only a few inches in its total diameter.

Not only the scientific side of all branches of biology, but also the philosophical or speculative side, have been developed during the old age of the tree, or during the last 300 years. In fact, modern zoölogy and inductive methods may be said to have begun with William Harvey in the seventeenth century.

It is true that when the tree began its life, men had ideas and conceptions of the principles underlying nature, but most of these were crude and inaccurate, based on mere hearsay or tradition, and differing but little from those held before the beginning of the Christian era.

The science of anatomy had been at a standstill since the time of Galen (A. D. 130). This brilliant anatomist, it is true, advanced the study of anatomy by his careful dissections of apes and some of the lower animals, and he also wrote extensively on physiology; but accurate as some of his observations were, his errors, particularly in physiology, were many. His works, however, remained authoritative for fully 1400 years; his statements overruled the demonstrations of nature, and he was so reverenced that whoever had the courage to dispute him was liable to persecution and ostracism.

Physiology was not materially different from metaphysics, and both were affected with superstition. The ancient belief that the body contained *four humors*—"blood," "phlegm," "yellow bile," "black bile"—was held, and Galen had added to these a "pneuma," which pervaded the whole body, mingling with the humors and supporting life. The proper mixture of four elements—heat, cold, wetness and dryness—constituted the normal individual. The administration of drugs was in accordance with this belief. Systematic zoölogy did not exist. There was no true conception of species, no accurate description of animals, and no adequate system of classification. The naturalists were merely compilers and copyists of Aristotle and other ancient writers, a most curious feature of their point of view, even as late as the early part of the eighteenth century, being their readiness to rely on what was said or written and their slowness to observe for themselves. The modern attitude of scientific

doubt seems not to have occurred to them and, like Sir Joseph Porter, they never thought of thinking for themselves at all.

The philosophical or speculative in biology was retained by the clergy, almost the only persons really interested in the conservation of documents, and as a class the only ones able to read and write.

Some of the Greeks had given explanations of the succession of organisms on the globe, and Aristotle, born 384 B.C., believed that the first animals arose from the ocean, and that low forms of life were constantly springing into existence by spontaneous generation, a fallacy that was not completely eliminated from biology until the nineteenth century.

Aristotle also perceived the principle of adaptation in nature, and considered the universe as the result of Intelligent Design. Such ideas of the Greeks had a marked influence on Christian thought for many centuries. Augustine (fifth century) believed that a living substance had been made by the Creator, and that from this had developed all the diverse organisms of the present time. Two other famous churchmen advocated similar views, Erigena in the ninth century, and Thomas Aquinas in the thirteenth, each the foremost scholar of his day. But naturally a wider and deeper knowledge of biological phenomena was necessary before philosophical biology could have a strong foundation. Hence the philosophy of zoölogy in its modern form, dates from the awakening of science in the seventeenth century.

From the time that the Big Tree was a mere seedling up to the time that it measured fully 13 feet in diameter, there was scarcely a single discovery in the field of natural science worthy of record. One event, however, which occurred when the tree measured only 12 inches in circumference, is of some interest. Silk was one of the treasures obtained from the Far East. Its production was carried on solely by the Chinese, who jealously guarded the silkworms and their eggs. The story is that two monks traveling in China succeeded in smuggling some eggs out of the country by concealing them in a hollow cane, and brought them into Europe. In the warm climate of the south the eggs developed into strong healthy worms. From such a humble beginning arose the extensive silk industry of southern Europe.

The stagnation of the study of anatomy for more than a thousand years was due to an extravagant admiration of Galen, over-confidence in his writings, and the failure of men to make observations for themselves, or to believe what they saw with their own eyes. Vesalius (born in 1514) was the first anatomist to assert independence, and to him is due the credit of laying the foundations of modern anatomy. Vesalius dissected the human body and accurately described what he found. He established a school of anatomy at Padua, and among his students was Fabricius, the teacher of Harvey, who startled the world in 1619 with his

discovery of the circulation of the blood. This discovery, which revolutionized the study of physiology, and gave new impetus to the study of anatomy, met with bitter opposition from the followers of Galen, but Harvey defended his views with success.

The opposition to Harvey set men to thinking, and investigation began. All forms of life were studied with all available means. Harvey, from an investigation of the development of the chick, laid the foundations of the study of comparative embryology, one of the four great supports of the theory of evolution; and he also propounded the theory of *Epigenesis*, a theory vigorously debated by philosophers for many years. The compound microscope, already mentioned, was applied to the study of organisms by Leeuwenhoek and Malpighi. The former demonstrated capillary circulation (1690) and discovered red blood corpuscles, infusoria and spermatozoa (1677). These spermatozoa were regarded by some as parasites of animal bodies, by others as embryos which only needed nourishment to develop into an adult form. Malpighi applied the microscope to the study of the chick, and his observations led him to announce the theory of *Preformation*, which was opposed to the epigenesis of Harvey.

The preformationists contended that a given organism contained within its sperm or ovum all the descendants of that individual with all organs and parts fully formed. In other words, embryos were only miniature adults, and were contained one within another like a series of Chinese boxes, in successive grades of size. The doctrine of epigenesis held that each sperm or ovum contained a relatively *homogeneous* living substance which became differentiated by gradual changes into a mature individual resembling the parent. Preformation was supported by Spallanzani, Bonnet, Haller and even Cuvier. Its absurdity was shown by the work of Wolfe (1759), who firmly established the doctrine of epigenesis as it is understood to-day.

The stimulus given to research by Harvey's discovery, the intercourse and exchange of views among men, and the voyages to all parts of the world resulted in an accumulation of a great mass of facts, which were of little value unless classified. Conrad Gesner (in 1551–1558) had given a complete bibliography of zoölogy, and was one of the most important of the earlier naturalists. About a hundred years later, Ray, an English zoölogist (1670), made an attempt to establish a "system of classification," but he had not the true conception of species. It remained for Linnæus to complete a system which served its purpose so well that it has remained practically unchanged to the present time.

Linnæus (1707–1778) was far and away the leading naturalist of his day, and his system of classification in which plants and animals were placed in groups according to clearly designated characters, was a great

advance over any scheme previously devised. His great service to science, however, was the perfecting of the binomial system of nomenclature, or method of definitely naming animals and plants. Up to his time animals were known by brief descriptions of their more evident characteristics written in Latin, as that was the universal language of science, and men of science (the term scientist had not then been devised). This descriptive method did very well so long as the number of known animals was small, but as the tide of commerce of the eighteenth century brought to Europe thousands of species before unknown, it became cumbrous. To overcome the difficulty, Linnæus devised the plan of giving to each animal two names: the first, a general or generic name which should indicate the particular group to which the animal belonged; the second, a special or specific name to apply to that kind of animal alone. To fix the name still more definitely, the name of the first describer of the species is now attached to the scientific appellation.

The Sequoia, for example, is known as *Sequoia washingtoniana* (Winslow), though unfortunately this particular species does not offer a good, clear illustration of the principles of binomial nomenclature.[1]

Buffon (1707–1788) was the first of the great founders of the modern doctrine of descent with evolution. He supposed, like Bonnet, that the main groups of animals had arisen in linear series, and he believed that the direct action of the environment brought about structural modifications that were inherited.

Erasmus Darwin (1731–1802), grandfather of Charles Darwin, was another of the early evolutionists. He pointed out, among other things, that the universal struggle for existence involved plants as well as animals. Unlike Buffon, he emphasized the indirect or responsive modifications produced by the environment, thus anticipating Lamarck, but like his predecessor, he assumed the inheritance of such changes.

It was Lamarck (1744–1829), the contemporary and fellow-countryman of Cuvier, who was the first to express the blood-relationship of organisms, as is done to-day, namely, by means of the *genealogical tree*. This eminent anatomist and investigator held views much in advance of his time. He rejected entirely the fixity of species, and believed that all animals now existing had been derived from a common stock by a process of gradual change. In one place he affirms that "Nature needs only

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[1]The name *Sequoia gigantea* is sometimes applied erroneously to the Big Tree, the correct name being *Sequoia washingtoniana* (Winslow) Sudworth. The question is considered at some length by Sudworth in Check List of the Forest Trees of the United States, Washington, 1908, pages 28, 29.

Briefly stated, *Sequoia gigantea* is a synonym of *Sequoia sempervirens*, the Redwood, and if for no other reason the rule "once a synonym always a synonym" adopted by zoölogists would prevent its being used for the Big Tree.

matter, time and space to produce all changes." The two factors which he believed most important in producing these modifications were the reaction of the organisms to their environment and the inheritance of the modifications resulting from this reaction and of the effects of use and disuse of organs.

Lamarck's theory was partially smothered in the ridicule which Cuvier heaped upon it. Cuvier was a firm believer in the immutability of species and his great authority in the biological field made him a powerful dictator of public opinion.

Among the naturalists of the eighteenth century, Goethe and Cuvier are conspicuous. The former (1796), although a great poet, made valuable contributions to science. He introduced the word "morphology" as a designation for the study of form or structure, and was the first to advance the *vertebral theory* of the skull, that is, that the skull represents modified vertebræ. He recognized the significance of vestigial organs, such as the gill slits in human embryos, hinder appendages in whales, etc., and predicted the discovery of the premaxilla in man—the supposed absence of which was considered to be a character which distinguished man from the apes.

It was, however, Georges Cuvier (born in 1769), the famous French naturalist, who was the recognized leader in zoölogical science for more than half a century. He stands as a striking example of a man who was remarkably correct in his observations of nature, but equally incorrect in his generalizations. His work on the Tertiary mammals of France marked the beginning of palæontology. He was the first to point out the resemblance between *Anchitherium* and the modern horse, a fact which is one of the strongest evidences of evolution. He was a preformationist and believed in *Catastrophism* (the theory that the earth as it is at present is the result of successive catastrophes), rather than *Uniformitarianism* (the belief that the present condition of the earth has been brought about by a gradual, uniform change). The work of Cuvier in comparative anatomy is also important, and he is called the founder of this science. He recognized the principle of correlated growth, and in "Le Règne Animal" improved the classification of animals.

The last century of our tree's life was remarkable for the discoveries in all branches of natural science. De Blainville (1839–1849) and Lyell (1797–1875) made valuable contributions to palæontology and geology. Lyell's "Principles of Geology" (1830–1833) dealt a death blow to catastrophism, and is a work equal in importance in its own field to the "Origin of Species" in biology.

Milne-Edwards (1800–1818) enunciated the principle of the physiological division of labor. Von Baer (1828) announced the law that bears his name, namely, "individual development is a recapitulation of race

development." Schleiden and Schwann (1838–1839) described cells in plants and animals, and propounded the cell theory. Valentin (1839) named the "nucleus," and was the first to speak of the "cell theory." Purkinje and von Mohl (1840) named the living substance of the cell *protoplasm*, a term in universal use to-day. De Barry (1843) observed the union of sperm and ovum. Kölliker (1846) demonstrated that spermatozoa develop in the tissues of the testes. Owen (1846) pointed out the difference between *homologous organs*, for example, the arm of man, fore limb of horse, and wing of bird, organs which are formed on the same structural plan, and *analogous* organs, for example, wing of bird and wing of butterfly, organs differing entirely in structure, but performing the same function.

Remak (1850) described "three germinal layers," and Huxley (1859) homologized them in the lower animals.

Rapid strides were made also in systematic zoölogy and in zoögeography. The relations of the lower animals were worked out by Leuckart, Vaughn, Thompson, Dujardin, Agassiz and a host of others.

Expeditions were sent out to explore the earth and the sea. Famous among these are the voyage of the "Beagle," on which Darwin served and did some of his earliest biological work; and the voyage of the "Rattlesnake," on which Huxley was Assistant Surgeon.

In 1859 Darwin published his "Origin of Species," a book which is universally admitted to have had more influence on human thought than any other work of the century.

Darwin's theory of the "Origin of Species" may be stated briefly as follows: All species tend to vary. No two individuals of the offspring of a pair are exactly alike. On account of this variation in structure or function, certain individuals are better able to thrive than their fellows. These animals transmit these characters to their offspring, which in turn survive in the struggle with their fellows. Thus nature eliminates those variations which are disadvantageous to the organism, each individual being tested in its struggle to maintain its existence. The accumulation of these favorable variations through many generations is supposed to produce an organism quite different from the original stock, or, in other words, a new form.

Few works have been constructed with more care and skill. For more than twenty years Darwin collected facts from all available sources, and made innumerable observations himself. The evidence in support of his theory was drawn from many branches of natural science: comparative anatomy, embryology, palæontology and zoögeography. So numerous were the facts that he presented, and so careful was the exposition of his theory, that in less than twenty years it became the working hypothesis of nearly every biologist.

Long before Darwin's time the resemblance between groups of animals had been recognized, indeed, even by Aristotle and others among the ancient Greeks, and many new facts made known by investigators from Vesalius onward emphasized the significance of these resemblances. In 1620 Bacon published "Novum Organum," in which he advocated the unity of nature. Descartes (born 1596), attempted to explain the universe on natural laws. Leibnitz (born 1646) advanced a theory of the continuity of organisms. The term "*evolution*" was introduced by Bonnet as a name of the process by which organisms had become differentiated. He expressed this relationship by introducing the idea of a "scale of beings," which formed the links of a chain. This conception has persisted up to the present time, in the expression "the missing link."

In 1844 a book called "Vestiges of Creation" appeared and caused quite a sensation. That this was published anonymously by its author, Robert Chambers, is significant of the attitude of the public toward the idea of evolution.

Naturally the "Origin" met with a storm of opposition, but it was vigorously defended by many newly won adherents, among whom was Huxley. He it was who perhaps more than any other scientist secured for the "Origin of Species" a fair and impartial consideration and thus aided the cause of truth.

Among the earlier champions of Darwin's theory were Lyell, Tyndall, Hooker and Spencer.

The last decades of the great tree's life witnessed astonishing developments in all branches of zoölogy. The number of known species has increased enormously, owing to the enthusiasm of collectors in all parts of the world, and especially through the work of expeditions sent out by governments and museums, one of the most noted of such expeditions being that of the English vessel, the "Challenger" (1872–1876), which brought back more than 8000 species new to science. Institutions established by civilized governments all over the world, like the United States Fish Commission, organized by Professor Spencer F. Baird, as well as the National Museum and the Geological Survey, have made great contributions to pure and applied science. The famous seaside laboratory founded at Naples by Professor Anton Dohrn in 1870 is a prototype of those at Woods Hole, Plymouth, Roscoff and others, all of which have materially aided in the advance of biological investigation.

Palæontology, too, has had a rapid growth. Cope, Marsh and Osborn in this country discovered and described more than a thousand new species of vertebrates, many of which are on exhibition in the Hall of Fossil Vertebrates. In invertebrate palæontology James Hall was one of the leaders, and a large part of the material upon which he did his monumental work is displayed in the Geological Hall.

Zoögeography, one of the foundations of evolutionary doctrine, began with Wallace's publication in 1876 of the "Distribution of Animals," the first complete treatise in this department, and the base for all further work.

A complete revolution in the theory and practice of medicine has been brought about through the application of biological knowledge. The studies of Louis Pasteur upon yeast and its life were the beginnings of bacteriology and protozoölogy, which deal with the minute organisms causing numerous diseases of man and of lower animals. What biologists have discovered about the causes of malaria, yellow fever, smallpox, and a host of other maladies has done more to alleviate human suffering than all the researches made prior to the time of Pasteur.

Since Darwin's time, the all-inclusive doctrine of evolution has become better understood and more clearly formulated, especially as regards the central process of heredity. For a long time after the "Origin of Species" appeared, the main question in dispute was concerned with the supposed inheritance of modifications acquired during the lifetime of an individual. Spencer was the chief representative of those who adopted the Lamarckian dictum that such was the procedure in the transformations of successive generations. Those who upheld Darwinism contended that only the congenital factors were effective, and that the transmission of individually acquired characters was unlikely on *a priori* grounds. The work of many investigators on the minute structure of the cell, and especially that of Weismann in the last decade of the tree's life, provided definite evidence that there was a concrete physical basis of heredity which followed such a course during the lifetime of an individual and in the production of offspring as to render the Lamarckian interpretation untenable. In the nuclei of all cells including the germinal elements is the deeply-staining substance called *chromatin*, which is derived equally from the two parental germs, and which is transmitted during the course of development to the germ-cells from which the offspring of the next generation arise, in a continuous and uninterrupted course. The chromatin bears the hereditary qualities of the species, in a way that is unknown in all of its details, but the fact remains that it does. Even the varied qualities of sex can be assigned to a specific number of the chromatin bodies. The results of breeding experiments with plants and animals, like those obtained even in Darwin's time by a monk, Gregor Mendel, in the obscurity of his Austrian monastery garden, are in entire accord with the fundamental tenets of Weismannism. In brief, such facts and many others lead inevitably to the conclusion that the essential things in inheritance and in evolution are the congenital qualities, and that the environment has only a limited value in a quantitative way.

The whole doctrine of evolution, and its principal statement relating to heredity, are extremely important for all those subjects which are

founded upon the study of the nature and biological relations of organisms, including man. Every department of human thought and life, social, religious, intellectual and industrial, has been profoundly influenced and modified by the marvelous discoveries of science which have occurred ever since this Sequoia attained gigantic proportions.

What progress, material as well as mental, has our Sequoia witnessed not merely in its lifetime, but in a small fraction of its lifetime. And what may the seedlings expect to behold, provided their career is not cut short by fire or ax? Which of Wells' two solutions of the World Problem will prove to be correct? Will mankind pass through existing conditions and, purged as by fire, rise to heights now undreamed of, or in the conflicts of jealous powers and principalities and the equally bitter conflicts of labor and capital under stress of economic conditions will existing civilization come crashing to an end and from the ruins of the present a future and better civilization evolve in the slow march of centuries to come? The Sequoia of the days to come will have lived through it all.[1]

[1]Written in February, 1914.

NEARING THE END
A Logging Camp at California Forest

CLIMATE AND HISTORY

AS RECORDED BY THE BIG TREES

As noted on page 11, the climate of the past 3000 years is recorded in the growth rings of the Big Trees, and the changes in climate and their effect on history have been given by Professor Ellsworth Huntington in the following series of labels prepared by him at the time of the International Eugenics Congress of September, 1921.

As he states, every "change of climate means a corresponding, though perhaps slight, change in man's racial character. These changes arise in four chief ways:

(1) Through the *food supply*, for climatic variations are the chief cause of famine.

(2) Through the *direct effect upon human health and energy*, for temperature, sunshine, moisture, and variability often determine how actively people work and whether extreme types can persist in a region.

(3) Through *disease*, including the effects upon (a) bacteria such as those of malaria, (b) bacterial carriers such as the mosquito, and (c) other human parasites such as the hook worm.

(4) Through the *migrations*, induced chiefly by the food supply. Such migrations often last long after their cause has ceased to act. They may affect people upon whom the climatic change made no impression. For example, in western China during the nineteenth century, some Dungan migrants, set in motion by drought, traveled perhaps a thousand miles. Each time they came to a halt for a few years they were forced to move on by the settled inhabitants. Such migrants may finally oust a settled community which in turn moves on and dispossesses a third group, and this may be repeated a dozen times.

Such migrations affect racial character in many ways:

(1) They produce the usual selective actions of wars.

(2) They also bring races into new habitats where new selective factors are at work.

(3) They are efficient causes of racial mixture, and thus of the development of new types."

"Attention is concentrated on the Mediterranean regions and western Asia because that is where our knowledge is greatest."

TROJAN DRY PERIOD

GREAT MIGRATIONS CULMINATING ABOUT 1240 B.C.

One of the *most confused and disastrous periods* in the entire course of ancient history. *Dry period* apparently began perhaps 1400 B.C., was mitigated in days of Rameses II, B.C. 1330, culminated about 1240 B.C. and reduced civilization to a low ebb in almost all parts of the ancient world. *Eugenically* its chief effect was an extraordinary number of *migrations* and *wars*, hence *great mixture of races* and rapid *natural selection* because of the *new environment* arising both from migration and from climate change.

SOME OF THE CHIEF MIGRATIONS:

(1) Aramæan Migration. Arab stock moved from Arabia into Mesopotamia, Syria, and Egypt. Wanderings of the Hebrews, the Khabiri of the monuments, appear to belong to this migration.

(2) Libyan Migration. Libyans from the western desert as well as Arabs from the east were forced by the drought to invade Egypt.

(3) Hittite Migration. Hittites from Asia Minor pressed southward to northern Palestine, also to northern Mesopotamia where they overthrew the Mittani, who in turn came into conflict with the Assyrians.

(4) Phœnician Migration. Pressure of migrations or of hunger caused the Phœnicians to colonize in North Africa and the Mediterranean Islands as never before.

(5) Greek and other Migrations. The Dorians started toward Greece, and the progenitors of the early Romans toward Italy; movements of allied peoples led to the Trojan War, the final fall of the old Cretan civilization, and the invasion of Egypt from the sea.

1200 TO 950 B.C.

PROGRESSIVE ERA

FAVORABLE STORMY PERIOD OF DAVID AND SOLOMON

At first a time when civilization in the Near East recovered slowly from the great migrations of preceding dry period. Then prosperity and empire building, e.g., Palestine under Saul, David, and Solomon; the progress and rivalries of Assyria, Babylonia, and Egypt.

During this period of greatest storminess, the centers of highest civilization were farthest south.

950 TO 740 B.C.

MEDIOCRE CLIMATE

DECLINE OF ISRAEL

Climatic conditions in western Asia better than now, but not so good as before and after. Drought and famines, as in time of Ahab about 870 B.C., a probable factor in the decline of Palestine. The Moabites on the dry east side of the Jordan where a diminution of rainfall is especially effective, probably illustrate what was happening in many other regions. They apparently changed from a peaceful, settled, agricultural life to a warlike, roving and sheep-raising life, especially in the dry period after 840 B.C., when they took to plundering the Israelites much as the Arabs now plunder the settled people of that same region.

740 TO 660 B.C.

SHORT PERIOD OF FAVORABLE CLIMATE

ASSYRIAN EXPANSION

Greatest expansion of Assyria under Tiglath-Pileser IV, Sargon II, and Esarhaddon, who penetrated to the extreme south of Arabia where an army could scarcely operate except when the climate was decidedly moister than now. At the same time "Moab regained all, and perhaps more than all, its former prosperity."

660 TO 450 B.C.

RELATIVELY DRY PERIOD

SCYTHIAN MIGRATIONS

Migrations perhaps no greater than during preceding dry period, but culminated in movements which left a more marked effect on history, and on racial distribution.

(1) Indo-Germanic or Scythian Migrations. Scythians began to move southward soon after 660 B.C. They broke over the civilized world about 624 B.C., penetrating to Syria, Palestine, and Egypt. They terrorized western Asia for about 30 years.

(2) Arab Migrations. A movement of the Arabs outward from the desert began about 640 B.C. The Nabatean tribes who later made Petra their headquarters probably came into eastern Palestine at this time.

(3) Medo-Persian invasions. The Medes, advancing from the dry Persian Plateau, invaded the irrigated region of Mesopotamia, taking Nineveh in 606 B.C. at the height of a dry period. The Persians followed them, taking Babylon in 538 B.C. during the next dry period.

450 TO 250 B.C.
HIGHLY FAVORABLE CLIMATE
GREAT GREEK PERIOD

At first prosperity and progress ruled almost everywhere in the dry regions of the eastern Mediterranean and western Asia. Events in other countries are largely overshadowed by Greece because of the concentration of genius among a small group of Athenians who were probably Nordics. Almost ideal conditions of climate helped to provide the health, vigor, and abundant food supply which seem necessary in order that genius may devote itself to the occupations that chiefly advance mankind.

250 TO 100 B.C.
PRE-CHRISTIAN DRY PERIOD
GREAT DECLINE OF CIVILIZATION

Not so dry as many later periods, but characterized by greatest known *change* of climate since the Trojan Dry Period a thousand years earlier. *Changes* are what count *eugenically.*

First clear evidence of strong selective influence of climate through health. From 400 to 200 B.C. malaria seems gradually to have increased in both Greece and Italy. Due in part to increasing contact with other regions, but perhaps even more to the decrease in rainfall. As the rainfall declined, the conditions of topography, drainage, and stagnant water in swamps and half-dry stream beds must gradually have become more and more favorable to the malaria-bearing mosquito.

Malaria, and perhaps other diseases, coupled with the increasing sunniness and monotony of the climate, may have had much to do with the complete breaking down of Greek civilization, and the serious collapse of that of Rome in the second century B.C. Such conditions not only weakened the people as a whole, but probably weeded out the more brilliant Nordic elements whose fair complexions and northern constitutions made them unable to stand the malaria and the long, dry, sunny summers.

100 B.C. TO 250 A.D.
FAVORABLE CLIMATE
HEIGHT OF THE ROMAN EMPIRE

Climatic improvement gave respite from malaria, mal-nutrition, barbarian migrations, misgovernment, and the weeding out of stronger northern elements. Rome's climate was probably not so good as in the great Greek period, but it was probably better than that of any other region at that particular time. Like Egypt, Babylonia, Assyria, Syria, and Greece, her greatest day was when she was most nearly unrivaled in climate, and her people were the most healthful and energetic.

250 TO 620 A.D.

DECLINE OF ROME

INCREASING ARIDITY

A long, hard period during which the climate grew progressively worse. Migrations, famine, poverty, misgovernment, plague, pestilence, inertia, and vice were dominant. The weeding out of the strong, vigorous northern types seems to have progressed apace in many regions where civilization had formerly been high, and especially in Rome. In regions like Egypt and North Africa, where the climate had now for many centuries ceased to possess highly stimulating qualities, the processes of racial readjustment had apparently done their work so that a certain degree of stability and even of recovery seems to have been attained. This may help to explain how it happened that when Rome was still staggering downward, North Africa was able to maintain a certain semblance of progress under the lead of men like Saint Augustine.

620 TO 880 A.D.

VERY DRY PERIOD

MOSLEM MIGRATIONS AND EUROPEAN DARK AGES

Terrible famines due to drought inclined the Arabs to pour out at Mohammed's call and conquer the world during the few decades after the Prophet's flight from Mecca in 622. The surrounding peoples, having also been weakened by the persistent drought, were unable to resist. Hence the Arabs spread with extraordinary speed and introduced new racial elements from Spain to Central Asia. Climatically the years from 620 to about 760 A.D. were probably the most unfavorable known to history. Central and western Europe, to be sure, seem to have had a stimulating climate, but there the chaos due to the preceding barbarian invasions had not yet had time to give place to a high civilization. Nevertheless the strongest element in civilization aside from the Arabs was probably the Franks under Charlemagne, and they were the people who lived where the climate was most stimulating.

880 TO 1100 A. D.

FAIRLY RAINY PERIOD

PAPAL AND ITALIAN SUPREMACY

Increased storminess once more made Italy a favored country. The temporal supremacy of the Popes at Rome harmonizes with the idea that the region with the most invigorating climate and presumably the best health, is likely to be dominant in world affairs.

1100 TO 1200 A.D.
DRY PERIOD
CRUSADES AND MONGOL OUTBURST UNDER JENGHIS KHAN

The Crusades must have had an important effect upon racial mixture. They reflect climatic influences in two ways. First, according to their own tradition, the Seljuk Turks began to migrate from Central Asia because of quarrels due to lack of rain in the extremely dry seventh century. Once started they kept on migrating, and about 1070 A.D. took Jerusalem. The Seljuk treatment of pilgrims was a chief reason for the Crusades. Second, in the Crusades the French and their neighbors played the chief part because they were the most energetic Christians of that time. This seems to accord with the fact that according to the curve of the Big Trees the climate had once more changed so that those regions had better health and more energy than any other parts of the Old World.

In the next century, 1200 to 1300, the continued dryness of Central Asia seems to have been one of the great reasons why the Mongols were so ready to follow Jenghis Khan and burst out from that dry region just as the Arabs were ready to burst from Arabia in the preceding dry period under Mohammed. Contented, prosperous people rarely or never undertake such enterprises. The Mongol outpouring not only mixed the blood of the Mongols with that of people of many sorts from the coasts of China to Poland, but set in motion other races such as the Turks, and killed off millions of individuals.

1300 TO 1400 A.D.
LAST GREAT STORMY PERIOD
THE BLACK DEATH AND THE REVIVAL OF LEARNING

This period, being near to our own day, furnishes much the best illustration of the varied happenings in different regions at times of extreme storminess. The following events are known to have occurred:

(1) Rapid growth of trees in California.

(2) Advance of ice on coasts of Greenland, change in sailing from Iceland to Greenland, difficulty in maintaining communication between Denmark and Greenland, southward migration of Greenland Eskimos who became warlike and finally exterminated the Norsemen early in the next century.

(3) Failure of crops in Norway, great distress, political upheavals.

(4) Worst famine ever known in England, 1315–16, due to excess of rain. Next worst in 1321; others in 1351 and

1369. Death and migration so reduced farm labor that wages were permanently raised 10 per cent.

(5) Severe drought, 1325, 1331, 1344, etc., alternating with extreme moisture.

(6) Terrific storms, floods, droughts and cold waves in regions near North and Baltic Seas, e.g., coldest winter ever known in Europe was 1323–4 when horses crossed ice from Germany to Sweden.

(7) Highly stimulating period in Italy. Revival of learning.

(8) Caspian Sea and Lop Nor in western China rose rapidly, indicating heavy rain as in California.

(9) Worst famine ever known in India due to scarcity of rain, 1344 onward. Mogul Emperor could not obtain the necessaries for his own family.

(10) Terrible famines in China due to delay of rains followed by floods in first third of century.

(11) Black Death or Great Plague began among famine-weakened people of China about 1333, spread over most of Asia and Europe before 1350, destroyed 13,000,000 people in China, and a third of those in England, France, Italy, and elsewhere. A tremendous factor in racial selection.

FOR THE PEOPLE

FOR EDUCATION

FOR SCIENCE

AMERICAN MUSEUM OF NATURAL HISTORY

Mammoths and Mastodons

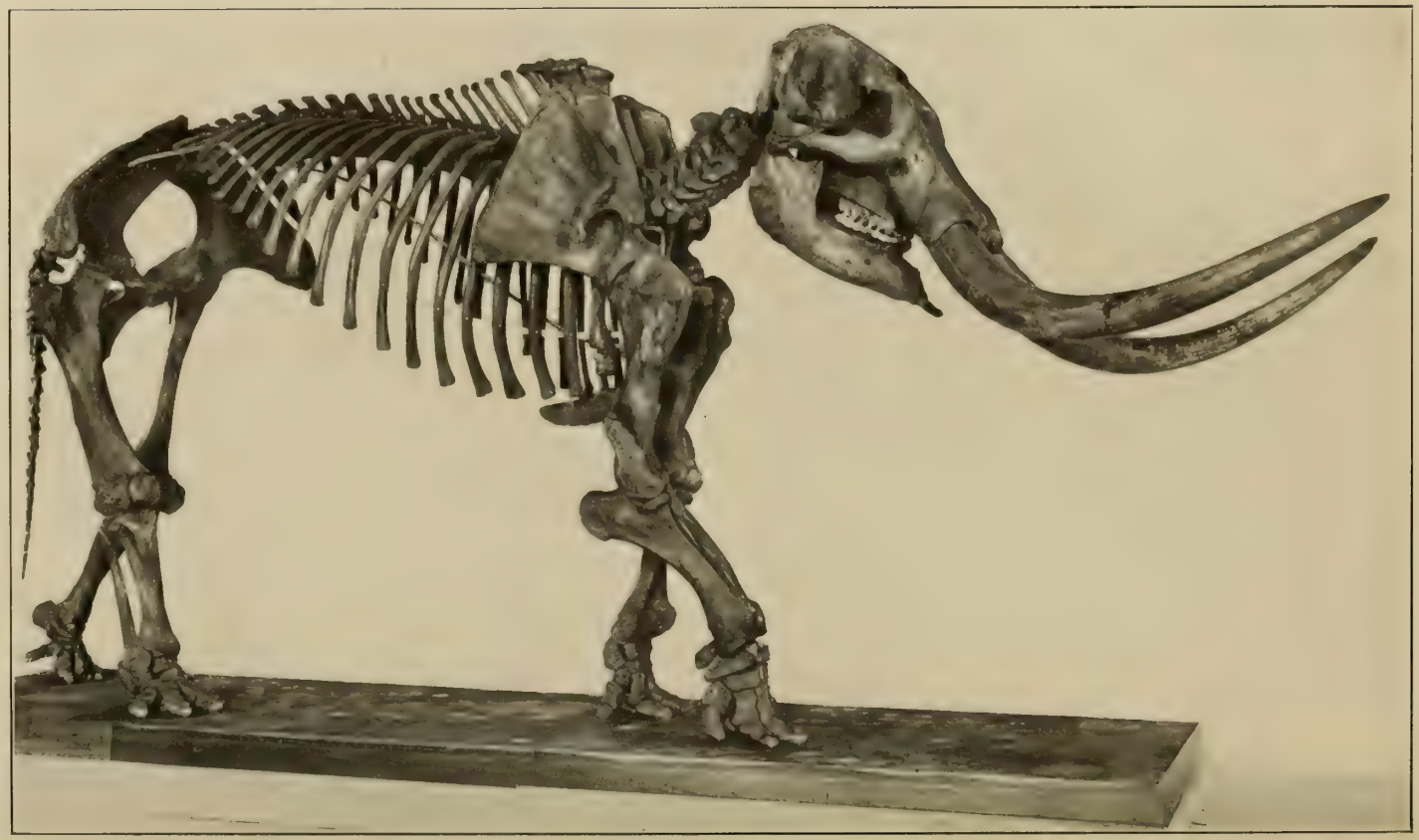
By

W. D. MATTHEW

THE AMERICAN MASTODON

Model by Charles R. Knight, based upon The Warren Mastodon skeleton in the American Museum of Natural History

No. 43 OF THE GUIDE LEAFLET SERIES.—NOVEMBER, 1915.



After Osborn

THE WARREN MASTODON SKELETON IN THE AMERICAN MUSEUM.

Mammoths and Mastodons

A guide to the collections of fossil proboscideans in the American Museum of Natural History

By W. D. MATTHEW

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I. INTRODUCTORY.

ELEPHANTS now inhabit only the warmer regions of the Old World. The Indian Elephant is native to southeastern Asia, the African Elephant to central Africa. Both are forest and jungle dwellers, avoiding the plains and deserts and unknown in cold or temperate regions.

Mammoths and mastodons, extinct relatives or ancestors of the existing elephants have been found in nearly all parts of the habitable world, except in Australia. During the Pleistocene or Glacial epoch they ranged in the Old World from the Arctic Ocean to South Africa, from Japan in the east to England in the west, and in the New World from Alaska to Patagonia. They were of many different species; some nearly related to the living Indian or African elephant, others more distant cousins. In the Tertiary formations of the Age of Mammals, which preceded the great Ice Age, remains are found in the Old World and in North America of more ancient and primitive kinds, and their evolutionary history has been traced back step by step to an ancestry of primitive mammals of comparatively small size with no trunk and very unlike a modern elephant in both teeth and tusks.

Fossil teeth, tusks and bones of the skeleton are very commonly found in the surface soils, clays and gravels, and especially in peat-bogs or drained lands and in river valleys. On account of their size they have always attracted attention. In olden days they were often attributed to giants,* and it is not unlikely that many of the circumstantial stories and myths of mediæval giants were suggested by discoveries of this sort.

Early in the eighteenth century the discoveries of fossil teeth and bones recognized as belonging to elephants, in France, Italy, Germany and England were currently explained as relics of those brought by Pyrrhus or Hannibal or Julius Cæsar. About the end of the century, however, Cuvier demonstrated to the world not only that these relics were found in many regions never invaded by these warriors of antiquity, but that they belonged to distinct species from those now living. He was not indeed the first to make this discovery; various learned men of his time or earlier had come to the same conclusion, but its general acceptance was largely due to the great influence of Cuvier.

Besides the true elephants of extinct species Cuvier distinguished the mastodons (μαστός=nipple, ὀδούς=tooth) with grinding teeth very different from those of elephants, although much like them in skull and skeleton.

In this country early discoveries of mastodon or elephant bones were also thought to be the remains of giants. Doctor Warren in his memoir

*This is not so absurd as it might seem, for most of the bones of an elephant skeleton are more like human bones, except as to size and massive proportions, than they are to most other large quadrupeds.

on the mastodon quotes an interesting correspondence between the learned Cotton Mather and Governor Dudley of New York, concerning the discovery of such bones on the banks of the Hudson near Newburgh. French explorers on the Ohio discovered great quantities of teeth and bones of mastodons and mammoths at the Great Salt Lick in Kentucky, and elsewhere along the river, and some of these were sent to France and studied by Cuvier and other scientists.

During the last century many fossil skeletons and skulls and innumerable teeth and bones have been found in all parts of the United States, in Alaska, Canada and Mexico and are preserved in various museums throughout the country.

Scientific notices of the fossil remains in America begin about 1750. They are mentioned by Thomas Jefferson in his Notes on Virginia, 1782, and noticed at more or less length by many other less distinguished authors, usually under the name of mammoth or elephant bones. Numerous descriptions and figures of the mastodon appear during the first half of the last century, culminating in the great memoir of John C. Warren 1852. Descriptions and notices of mammoths or other fossil elephants are hardly less numerous in American scientific literature of the last century, but no adequate treatise dealing with them has yet been published, nor is there any general treatise on the fossil proboscideans of the world. The literature is scattered and the subject much confused.

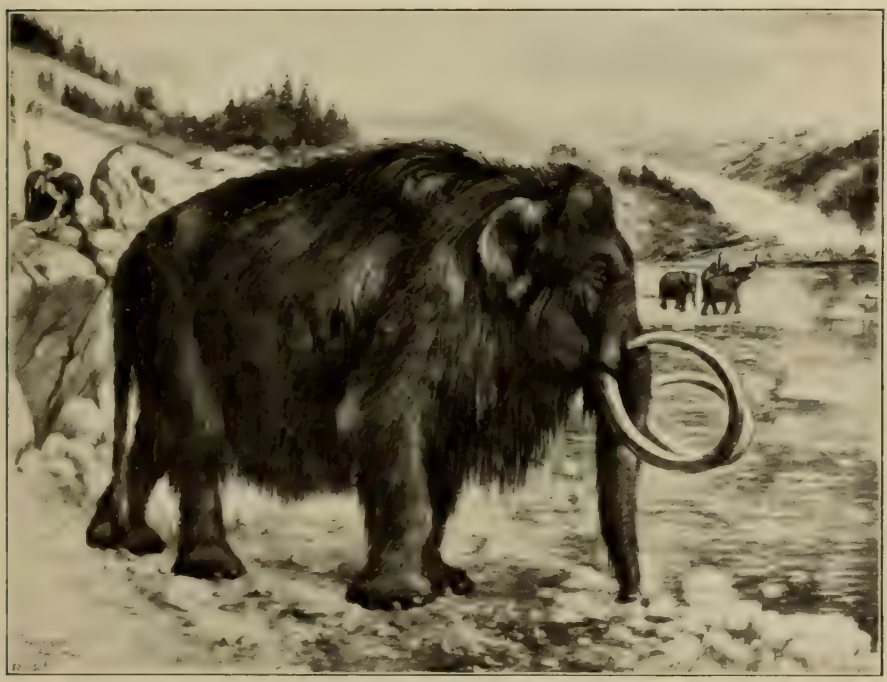
II. THE EXTINCT ELEPHANTS.

Genera, Elephas, Loxodon, Stegodon.

THERE are at least ten or twelve species of extinct elephants known in different parts of the world. Some are nearest to the modern Indian elephant (*Elephas*), others to the African species (*Loxodon*), while others (*Stegodon*) are intermediate between these and the older mastodons. Three species are found in North America, three or more in Europe and northern Asia, the remainder are chiefly known from India and the Mediterranean region. Probably there will be more when the world has been more thoroughly explored.

The Mammoth. The best known of all the extinct proboscideans is the mammoth, *Elephas primigenius*. It was a near relative of the Indian elephant, but adapted to live in cold climates, and covered with a heavy coat of long coarse black hair with thick brown underwool. The most abundant and perfect remains of this animal have been found in Siberia, and it is often called the Siberian mammoth, but it ranged through all the countries of the north—in Europe as far south as Spain and Italy, in North America as far south as North Carolina and California. It was able to endure the most severe cold, for its remains are found in greatest abundance

on the shores of the Arctic Ocean and buried in the frozen tundra of northern Siberia and the gold-bearing gravels of Alaska and northern Canada. Entire carcasses, with flesh and hide preserved more or less completely, have been discovered in Siberia. One such specimen, found by the explorer Adams in 1799 on the banks of the Lena, and another discovered on the Beresofka in 1901, are mounted in the Petrograd museum. Similar remains, only less complete, were found by Quackenbush on Kotzebue Sound, Alaska, and are in this museum. The contents of the stomach show that these animals fed upon the same vegetation, grasses and sedges, birches, alders, poplars, etc., that prevails today in the far north. The deeply frozen soils and gravels in which their remains occur were accumulated by the overflow



After Osborn

Fig. 1. Restoration of the Mammoth, *Elephas primigenius*, by Charles R. Knight.

and freezing of river sediments during a long and bitter winter, which the short summer season was not sufficient to melt except on the surface. There is no doubt therefore that the mammoths of Siberia and Alaska lived in an arctic climate. The range of the species southward as far as southern Europe and the United States is directly associated with the advance of the great ice sheets which extended southward from Labrador, Keewatin and the northern Cordilleras, as far as New York and the irregular line of

the great terminal moraine that crosses the northern states. In Europe similar ice sheets extended southward from Scandinavia across Great Britain and Germany and radiated outwards from the Alps, Carpathians and Pyrenees. The mammoths and other northern animals followed the ice sheets southward and ranged beyond their limits in the cooler temperatures that accompanied them.

With the mammoths came also the hardy huntsmen of the north—tall, active and intelligent races of men, whose pursuit was no doubt an important factor in their extinction. In compensation they have left us sketches and rude paintings of the great prehistoric beast, preserved on bone or ivory and on the walls of caverns in southern France and Spain. These sketches, crude and impressionistic as they are, have been of no small assistance in completing and rendering more lifelike the reconstructions of the mammoth made by Mr. Knight under Professor Osborn's direction.

After Lucas

Fig. 2. Drawing of the mammoth on ivory, by a prehistoric French artist.

A characteristic feature seen in all these drawings is the great boss of wool or hair on top of the head. This was not preserved in either of the two Siberian carcasses, and would not be suspected from the form of the skull. It gives the animal a noticeably different aspect from any previous restoration.

Alaskan mammoths. Gold mining in Alaska and the Klondyke has resulted in the discovery of numerous teeth and bones of the mammoth and a few skulls, but no complete skeleton has yet been recovered. In 1908 Mr. L. S. Quackenbush secured for the Museum considerable parts of a mammoth carcass from the margin of the frozen tundra at Elephant Point, Eschscholtz Bay. There had been much more of the specimen, but most of it had been destroyed and the remainder badly disorganized by erosion and sliding of the face of the bluff in which it was exposed. The tusks and lower jaws, pelvis and hind limb, several vertebrae and numerous fragmentary bones and pieces of skin, masses of hair and wool, flesh and fat were preserved. The principal parts are in the museum's

exhibit.[1] The remarkable freshness of these remains is due to their burial in soil permanently frozen ever since their entombment. They are probably many thousand years old. There is no reason to believe that the mammoth is still living in Alaska or has become extinct within the last few centuries. Various stories have appeared in the magazines and news-

After Osborn

Fig. 3. Molar teeth of extinct American elephants. Above, the mammoth, *E. primigenius;* middle, Columbian elephant, *E. columbi;* below, Imperial elephant, *E. imperator.* All x ¼.

papers of the survival of the animal in the more remote parts of the territory, and its being seen or even captured by white men. All of them may be set down as purely mythical, and the alleged tradition among

[1]Quackenbush, L. S., 1909, Bull. Amer. Mus. Nat. Hist., vol. xxvi, pp 87-130, pll. xvii-xxv.

the Eskimo of such an animal still existing is probably the result of inquiries by white explorers who provided the natives with the evidence as to appearance and habits of the animal. There is nothing impossible about these stories, but investigation has failed to show any valid evidence for them.

Skeleton of the Mammoth from Indiana. This fine skeleton was discovered on the farm of Dora S. Gift near Jonesboro, Ind., and purchased for the Museum in 1904. The feet and some of the limb bones were missing, otherwise it was fairly complete. The tusks were complete and in position when first found, crossing each other as in the mounted skeleton. This was demonstrated by sounding with an iron rod in the muck in which the skeleton lay buried. Unfortunately they were badly damaged by the finder in an unskilful attempt to get them out. After purchase by the Museum the tusks were repaired and the missing bones modelled in plaster mainly from casts of the fine skeleton of an allied species in the Paris museum, and the skeleton was mounted in 1906. The pose is based upon careful studies of the Indian elephant. The skeleton was at first thought to represent the Columbian elephant, but recent studies by Dr. O. P. Hay led him to conclude that it should be referred to the true mammoth. The restored limb and foot bones are probably somewhat too large and robust.[1]

Size of the Mammoth. It would be natural to suppose that this animal was so called on account of its gigantic size. In fact, however, the derivation of the word is the other way about—the name of the extinct monster has passed into a synonym for hugeness and massive proportions. It is derived originally from the old Tartar designation, *mama 'ntu*, by which the remains found in Central Asia were called when first brought to the knowledge of western nations. The name is said to signify "earth-mouse" and to be connected with Chinese legends concerning the animal which lived underground and perished when it came to the light of day.

The northern mammoth was not in fact any larger than the modern Indian elephant, despite exaggerated notions as to its proportions. It was not as tall nor as bulky as the largest African elephants, nor was it as large as some of the other extinct species of more southerly range. The skeleton mounted in this museum probably represents the maximum size; the Siberian mammoths and those from Alaska are considerably smaller.

The Columbian Elephant, *Elephas columbi* Falconer, is a near relative of the mammoth and the Indian elephant, distinguished by the coarser plates of the teeth, and attaining a somewhat larger size. It inhabited most of the United States and Mexico, its range overlapping on the mammoth to the north and the Imperial elephant to the southwest. It is

[1]Osborn, 1907, Bull. Am. Mus. Nat. Hist., vol xxvii, pp. 255-257.
Hay, 1912, Ann. Rep. Dept. Geol. Nat. Res. Indiana for 1911, pp. 719-722.

finely represented in the American Museum by the large male skull from Whitman Co., Washington, and female skull from Dallas, Texas.

The Imperial Elephant, *Elephas imperator* Leidy, is a still larger species, with decidedly coarser enamel plates in the grinding teeth, and gigantic

After Osborn

Fig. 4. Skull and jaws of Columbian elephant (male) from Whitman Co., Washington. About one-tenth natural size.

tusks. It attained a size equal to the largest living African elephants, the height at the back between twelve and thirteen feet, the tusks ten inches in diameter and measuring 13 ft. 6 inches along the outer side of the curve

in a specimen from Victoria, Texas, in the American Museum. This elephant inhabited Mexico and the southwestern portion of the United States in the early Pleistocene, followed apparently by *E. columbi* during the later glacial stages. Jaws and teeth from various localities from Oregon to Guatemala are shown in the wall cases.

Extinct Old World Elephants. In the older Pleistocene of Europe, especially the Mediterranean coasts, two very large elephants are found—the Southern Elephant, *E. meridionalis*, corresponding to the Columbian elephant in this country, and also nearly related to the Indian, and the Ancient Elephant, *E. antiquus*, with affinities to the modern African species. These species ranged over large portions of Europe, southern Asia and Africa. In the islands of the Mediterranean have been found remains of pigmy elephants, dwarfed probably as a result of being isolated on the islands after they were separated from the mainland. Distinct pigmy forms have been described from Malta, Crete and Cyprus.

Pliocene and Pleistocene Elephants of India. *Evolution of Elephants from Mastodons.* Numerous skulls and teeth of fossil elephants have been found in the Siwalik and later formations of India. Besides the more typical species there are several which are intermediate in tooth structure between the elephant and the more ancient mastodons of the Tertiary formations, and are placed in the genus *Stegodon*—*S. latidens*, *S. clifti*, *S. insignis*, with tremendously long tusks little curved, and others. These intermediate stages, found only in southern Asia, indicate that it was in this region of the world that the elephants evolved out of the ancestral mastodon groups.

III. THE AMERICAN MASTODON.

Genus **Mastodon** (=*Mammut*)

NEXT to the mammoth this is the most familiar and best known of all the fossil proboscideans. Indeed, it is much more common in this country than the mammoth, and it has been stated that there are many more mastodon skeletons in museums of the United States and Canada than there are of modern elephants.

The mastodons of this genus were contemporaries of the mammoth, and like them ranged widely over the northerly parts of the world. They equalled or exceeded the largest mammoths in bulk, but were not so tall, the limbs being shorter while the body is broader and more massive.

Teeth of the Mastodon. The tusks are similar to those of the mammoth but the skull and jaws are of different proportions, not nearly so deep and short as those of elephants, and the teeth are of quite different type. They are much smaller and shorter crowned, and instead of the successive

plates of enamel alternating with dentine and cement, the grinding surface shows two, three or four cross crests with intervening valleys and no cement. These teeth are adapted for chopping the food, like those of the tapir. The elephants on the other hand grind the food as does the horse. The teeth of the mastodon are but little different from those of his Tertiary ancestors —Cuvier included them both under the same genus—but what difference there is is a perfecting of the chopping tapir-like type. As in the elephant they are gradually pushed forward in the jaw during wear, and break off at the front of the grinding row when worn down to the base. But there are usually two or three on each side of the jaw in use at one time instead of one or parts of two as in the elephants. A young adult will have three teeth on each side of each jaw—twelve grinders in all; in an old animal these are reduced to two, rarely to one in extreme age.

Habits and Environment. The wide differences in grinding teeth are doubtless correlated with differences in the food and range. The mastodons seem to have been especially abundant in the heavily forested regions

After Lucas

Fig. 5. Grinding teeth of mastodon and mammoth.

of the north. They are rare in the open tundra regions of Alaska and Siberia and in the plains and deserts of the western states and are most abundant in the heavily wooded sections of the eastern states, as far west as Michigan and Iowa and as far south as the Carolinas.

Their remains have been chiefly found in the course of drainage canals and ditches in the swamps and boggy lands in this part of the country, where no doubt they were mired and so preserved from decay. The boggy valleys southwest from Newburgh, N. Y., and swampy districts in central Indiana, Ohio, Illinois, Michigan and Iowa have yielded many skeletons, skulls and other parts. Nearly all these remains are of post-glacial age, showing that the animal was abundant in this country after the glaciers had retreated. It has not been found in any of the formations older than the Pleistocene. The contents of the stomach have been preserved in two or three skeletons and show that they fed on the twigs of hemlock, spruce and other evergreen trees, but probably they were not restricted to this diet. Remains of the hair of dark golden brown color, long, dense and shaggy, are recorded as preserved with a skeleton found in Ulster Co., N. Y.

The Warren Mastodon. This skeleton is the most perfect one ever discovered; it is a male of very large size. It was found at Newburgh in 1845, on the farm of Nathaniel Brewster, and purchased by Professor John C. Warren of the Harvard Medical School for his private museum. Doctor Warren published a memoir in 1852[1] describing it fully and discussing its habits and affinities, a classic treatise which is still the principal source of scientific knowledge of the American Mastodon. In it he also describes the Shawangunk Head—a finely preserved skull and

Fig. 6. Skull of the American Mastodon, one-eleventh natural size. This is the well known "Shawangunk skull" found at Scotchtown, Orange Co., N. Y., and figured by Warren in his memoir.

jaws of the largest size found at Scotchtown, Orange County, N. Y. Both these specimens along with the rest of the Warren Collection were purchased for the American Museum by Mr. J. P. Morgan in 1906. The skeleton has been remounted, the original tusks being repaired and set in position in place of the papier-maché models used by Dr. Warren for his mount.

Male and Female Mastodon Skulls. Two skulls from Indiana illustrate the very marked differences between male and female of this species. The male has a much larger skull, the crests at the back higher,

[1]Warren, 1852, The Mastodon Giganteus of North America, pp. i-viii, 1-219, and 28 plates.

the tusk sockets much heavier and longer. The tusks in the male are six to eight inches in diameter and six to eight feet or more in length. The tusks of the female are only three or four inches in diameter and four to six feet in length. The grinding teeth are much alike. There are no tusks in the lower jaw of the female mastodon, but in the adult male there is frequently a pair of small peg-like vestigial tusks, sometimes only one. These fall out in old individuals and the socket closes up; sometimes they are not present in young adult males. Various specimens in the wall case illustrate the presence or absence of lower tusks in the two sexes. Of the two skulls in separate case the larger is the *Ashley skull* found near Ashley, Indiana, in 1909; the smaller is the *Fulton skull* found near Fulton, Indiana, in 1915. A fine palate with tusks, two pair of lower jaws, separate tusks and parts of skeleton were found with the Fulton skull and are shown in the wall case. All belong to females of different ages, the complete skull being the oldest.

Distribution of the Mastodon. The American mastodon ranged all over the United States and Canada, and has been found in Alaska, Siberia and as far east as central Russia (Podolsk). In the wall case are shown specimens from Florida, Georgia and South Carolina illustrating its southern distribution, from Kansas, Texas and southern California, illustrating its western and southwestern occurrence, from Point Barrow, Alaska (collected by Vilhjalmar Stefansson), showing its northern range, casts of teeth from Russia to show its occurrence in the Old World. The closely allied species, *M. borsoni* is recorded from numerous localities in eastern Europe and Siberia.

IV. THE LATER TERTIARY MASTODONS.

Genera **Dibelodon, Rhyncotherium, Tetralophodon, Trilophodon.**

MIOCENE and Pliocene with some survivors in the Pleistocene (Glacial) epoch.

These proboscideans preceded the elephants and great mastodons of the age of man. They are of smaller size and include quite a variety of different types, some of which, in the Old World, are believed to be ancestral to the elephants (through *Stegodon*, see p. 24), while others probably gave rise to the American Mastodon. Most of the Tertiary mastodons, however, are more or less clearly off the direct line of descent, and their exact phylogeny is not yet certainly known. We will point out here only the general relations and distribution of the different types, so far as known.

The Two-tusked Mastodon.

Genus Dibelodon (=*Stegomastodon*). Pliocene of North America,

with a few survivors in the Pleistocene. Chiefly Pleistocene in South America, with a few precursors in late Pliocene.

Upper tusks large, up-curved or straight, with or without enamel band. Lower tusks vestigial or absent (usually absent). Cheek teeth short-crowned, the anterior molars falling out early in life, so that the young adult retains two and old individuals only one molar. The second molar has three cross crests, the last five to eight. The crests are not clearly defined as in the American Mastodon, but composed of a pair of conical cusps with a number of smaller cusps interposed, arranged in a trefoil pattern, so that the valleys between the crests are blocked in the middle instead of running clear across as in the later form. This is the primitive form among the mastodons, and appears in most of the Tertiary types with variations in the number and arrangement of the minor cusps, grouped customarily into the "single trefoil" and "double trefoil" type.

This genus therefore is a derivative of the primitive mastodon type (*Trilophodon*) of the Miocene, paralleling the elephant phylum in (1) loss of lower tusks and shortening of the jaw, (2) increase in size of the upper tusks with tendency to upward curvature and loss of enamel band, (3) reduction in the number of functional teeth, the last molar becoming the principal grinder.

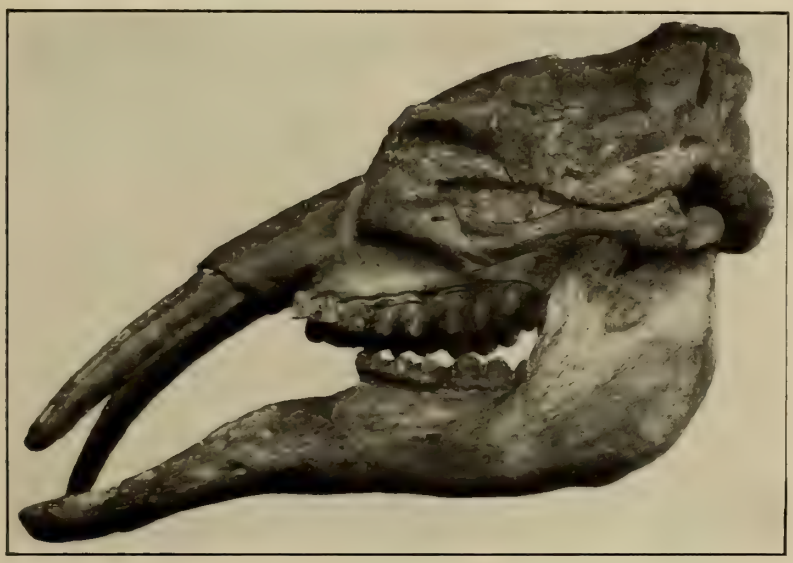
The typical form is *D. mirificus* Leidy, the characteristic species of the Pliocene of North America, well represented by the fine skull and jaws and several other specimens from the Blanco formation of Texas, showing different stages of wear in the teeth. All the South American mastodons belong to this genus. They are chiefly from the Pleistocene formations ranging from Columbia to Argentina, but some may be as old as the late Pliocene.

The Long-jawed Mastodon Tetralophodon. This group of Tertiary mastodons is notable for the great elongation of the jaws in some species. The powerful upper and lower tusks are but little curved and directed forward. The enamel bands are preserved on both. The species are readily distinguished by the second molar which has four crests instead of three; otherwise the grinding teeth are much like those of *Dibelodon* but the anterior molars retained longer in use. It is characteristic of the Upper Miocene and early Pliocene of Europe, Asia and North America. The typical forms are *T. longirostris* and *arvernensis*, of Europe, and in this country *T. campester*, of which the type is shown in the wall case. In *T. arvernensis* the jaw is comparatively short with small lower tusks. Casts of jaws of the European species are exhibited in the wall case.

The Beaked Mastodon Rhyncotherium. In this genus the upper tusks are also stout, little curved and with enamel bands, but the

jaw is rather short, and the lower tusks and their sockets turned down at a sharp angle to the plane of the grinding teeth. It is a rare form, and the only representatives that we have found are from the Pliocene of Texas and Pleistocene of Mexico.

The Primitive Four-tusked Mastodons. Genus **Trilophodon** (= *Gomphotherium*). This group includes a large number of species from the Miocene of Europe, Asia, Africa and North America, representing the ancestral stock of the various later types of mastodons and probably of elephants. The typical form is *T. angustidens* Cuvier of Europe, a species with exceptionally long lower jaws and tusks. In this country it is admir-



After Osborn

Fig. 7. Skull of Primitive Mastodon, *Trilophodon productus* from Miocene of Texas. One-tenth natural size.

ably represented by *T. productus* Cope. The upper tusks are straight or slightly down-curved, the lower tusks well-developed, and both carry a strip of enamel. Two or three grinders are normally in use at once, and the second true molars have three cross crests. In one group (*Bunolophodon*) the cross crests are strongly trefoiled; in another (*Zygolophodon*) they are more ridged, the valleys less obstructed, approaching the American Mastodon in type. Different species in the first group approach more or less to *Dibelodon*, *Tetralophodon* and *Rhyncotherium* in the characters of the grinding teeth.

Although chiefly from the Miocene, there are several imperfectly known Pliocene or even Pleistocene species referred to it. These represent

survivals. The perfect skull and jaws of *T. productus* in the end case illustrates the primitive features of these Miocene mastodons.

The oldest mastodons from this country are from the Middle Miocene (*Merychippus zone*), and are too fragmentary to base any important conclusions upon their characters. They are shown in the wall case. *T. euhypodon* of the Upper Miocene and early Pliocene is well illustrated by the type specimen. *T. serridens* (very close to *T. turicensis* of Europe) of the Upper Miocene and *T. brevidens* of the Middle Miocene represent the *Zygolophodont* group, approaching the American Mastodon.

Dinotherium. This extinct proboscidean is found only in the Miocene and Pliocene of the Old World, and is very different from the contemporary mastodons. The cheek teeth have but two cross crests, except for the first molar which has three. The tooth row in the adult has five or six teeth, the premolars being retained while the true molars come into use. There are no upper tusks, and the *lower tusks* are large, stout, and *curve downward* to a right angle with the tooth-row. The skull has the general form of the later mastodons, and the animal undoubtedly had a long and heavy trunk. The body and limbs were proportioned much as in the American Mastodon. *Dinotherium* is chiefly found in the Miocene formations of Europe. A gigantic skeleton discovered in the Pliocene of Roumania exceeds the largest American mastodons in size. Smaller species are also found in Algeria and Tunis, in British East Africa, and in India. It is unknown in the New World.

Casts of palate, jaws, teeth and forefoot of different species of *Dinotherium*, chiefly from the Warren Collection, are shown in the Museum exhibit.

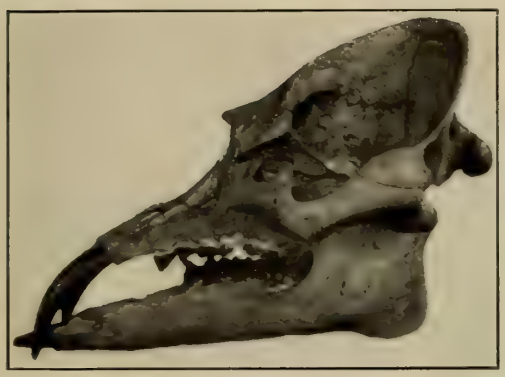
V. THE EARLY TERTIARY ANCESTORS OF THE MASTODONS.

Genera Palæomastodon, Mœritherium.

PALÆOMASTODON is chiefly known from the Lower Oligocene of the Fayûm district in Egypt but fragmentary remains have been recently found in the Gaj horizon of northern India, the lowest fossiliferous level of the great series of the Siwalik Hills. Its discovery and description are due to C. W. Andrews of the British Museum. It is unquestionably a primitive proboscidean, much smaller and more generalized than the earliest mastodons but showing clearly the especial characteristics of the order.

The upper tusks are small, down-curved, with enamel over the whole outer surface. The lower tusks are small, spatulate, and both upper and lower tusks have definite roots instead of growing from persistent pulps as do those of all later proboscideans.

There are five or six grinding teeth on each side of the jaw, twenty to twenty-four in all. The anterior premolars are simple crested teeth of a type very much like those of other primitive ungulates. The molars and last premolar have three cross crests; the third molar has also a crested heel.



After Osborn

Fig. 8. Skull of Palæomastodon, Lower Oligocene ancestor of the mastodons and elephants. One-tenth natural size. Fayûm district, Egypt.

The skull although primitive has the characters of proboscideans in the depression of the grinding series much below the level of the base of the cranium, the position of the openings for the nostril (anterior nares), set far backward and but little in front of the eye-orbits, the nasal bones much reduced and the entire construction of the face adapted for the accommodation of a trunk which, while evidently much less developed than in the modern elephants or the mastodons, must have reached a considerable length. The cranium is built out above the brain-case with cellular bony tissue to a considerable extent, but much less than in the later proboscideans.

After Osborn

Fig. 9. Head of Palæomastodon modelled by E. Christman under direction of Professor Osborn. One-tenth natural size.

Skulls of *Palæomastodon*, and also of the more problematic genus *Mœritherium* are shown in the end case. Below them are palatal views of the jaws and teeth of the same genera, and above are the carefully studied life-size reconstructions of the heads of the two genera, modelled directly upon the fossil skulls by Mr. Erwin Christman under direction of Professor Osborn.

Mœritherium is likewise from the Fayûm district, where it accompanies *Palæomastodon* in the Lower Oligocene, but is also found in the older beds of late Eocene age beneath this horizon. It has therefore been regarded as representing the later Eocene ancestor of the proboscideans. Its proboscidean characters, however, are by no means so clearly shown, and its ancestral position is open to serious question.

After Osborn

Fig. 10. Head of *Mœritherium*, modelled by E. Christman under direction of Professor Osborn. One-tenth natural size.

The skull is quite unlike any proboscidean type, having a long middle region and rather short face, with no suggestion of any trunk. There is a full set of upper incisors and two pair of lower incisors, but the second upper and lower incisor are enlarged into stout short tusks, the upper projecting downward, the lower forward and upward. The cheek teeth are six in each jaw, the three premolars of a simple primitive-ungulate type, the true molars each with two pair of rounded cusps, imperfectly united into cross crests, the third lower molar with a distinct heel.

Dr. Andrews cites[1] the following characters in support of the proboscidean affinities of *Mœritherium*.

1. The large size of the nasal opening, its somewhat backward situation and the small size of the nasal bones.

2. The commencement of the development of air-cells in the bones of the back of the skull.

3. The enlargement of the second incisors in both jaws to form tusks.

4. The transversely ridged character of the molars.

5. The spout-like anterior portion of the lower jaw.

[1] Andrews, 1908, Guide to the Elephants Recent and Fossil. British Museum, London.

Against this view it has been pointed out[2] that none of these specializations are carried in *Mœritherium* to a degree that would serve to place it conclusively or definitely as proboscidean. All of them may readily be matched in various other living or extinct mammals which certainly have no proboscidean affinities. *Mœritherium*, although supposed to be the immediate ancestor of *Palæomastodon*, differs from it more widely than it does from the Miocene mastodons, separated by a much wider gap in time. And some of the differences appear to be not primitive characters but divergent specializations from the primitive ungulate type.

VI. THE EVOLUTION OF THE PROBOSCIDEA.

IN the preceding sections we have sketched briefly what is known about fossil elephants and mastodons, and their ancestors in the Tertiary period. The principal types are shown in the American Museum exhibit.

These fossil skulls and skeletons carry the ancestry of the proboscideans as far back in geological history as the Eocene. Although we do not regard *Mœritherium* as a direct ancestor of *Palæomastodon*, it represents in many respects the primitive type of ungulate from which the proboscideans were derived.

Mœritherium is an animal of quite moderate size; it has no indications of a trunk; the head is long and low, the brain-case small with little or nothing of the cellular bony cover that builds up the later proboscidean skull into so remarkable a bulk. The teeth have departed relatively little from the primitive type common to all early mammals, of three incisors, a canine, four premolars and three molars in each jaw—44 teeth altogether. A pair of upper and lower incisors have been enlarged, the third lower incisor lost, and each molar has two pairs of cusps on the crown, not yet fully united into cross crests. The posterior premolars have taken on in part the character of the molars. Little is known of the skeleton save that the limbs were of moderate length, the knee much more bent than in the later proboscideans.

Palæomastodon is clearly of proboscidean type, and there is a wide structural gap between it and *Mœritherium*. The enlarged pair of incisors are much elongated and the enamel confined to the outer face. The long forward reach and moderate downward curvature of the upper incisors, the great length of the front of the jaw and close set lower incisors, pro-

[2] Osborn, 1909, Nature, Vol. lxxxi, p. 139. The problem of the affinities of Mœritherum is here discussed at some length.

Professor Osborn concludes that: "It would not be far from the truth to say, from our present knowledge of the animal, that Mœritherium is an offshoot of the Proboscideo-Sirenian stock, with *slightly* nearer kinship to the elephants than to the Sirenians." See also Dr. Andrews' reply to the above (ibid., p. 305), concluding as follows: "On the whole it seems that the weight of evidence is in favor of regarding Mœritherium as a proboscidean, though perhaps not on the direct line of ancestry of Palæomastodon, and retaining some characters of the original Proboscideo-Sirenian stock."

Fig. 11. Molar Teeth of Proboscidea. Above, elephants, living and extinct:—from left to right Imperial and Columbian elephants, Mammoth, Indian and African elephants. Below, mastodons and primitive types:—from left to right *Mæritherium*, *Palæomastodon*, *Dinotherium*, *Trilophodon*, *Mastodon*.

jecting forward and slightly downward are characteristically like the most primitive of the Miocene mastodons (compare *M. productus*). Three of the four premolars are still retained in the adult, but the construction of the molars, with their three cross crests, is unmistakably a near approach to the early mastodons. The skull is no less clearly that of a primitive proboscidean, in the depression of the palate and grinding teeth far below the level of the base of the cranium, the withdrawal of the anterior nares (opening for the nostril) to accommodate a flexible upper lip lengthened out undoubtedly into a trunk of considerable length, and various other particulars. It is obviously widely different from *Mæritherium*. The skeleton is only partly known, but is more clearly of proboscidean type, with short rounded five-toed feet, rather long and nearly straight limbs, short neck and deep compact body. The heavy foot-pads seem to have been much less developed than in the elephant, the heel much more primitive and resting nearly on the ground.

Dinotherium of the European Miocene, a contemporary of the Mastodons is an aberrant side branch of obscure ancestry. It can hardly be a descendant of *Palæomastodon*, since the molars (except m$_3$) are decidedly simpler having only two crests, and the premolars are likewise of simpler construction. The grinding teeth indeed are more readily derived from those of *Mæritherium*. The skull, however, is highly specialized for a large and long trunk, no upper tusks are known, while the lower tusks are very large, long and stout, curving downwards to a right angle with the grinding teeth. The skeleton is thoroughly proboscidean in type, with long limbs and elephantine feet and the latest species *D. gigantissimum* reached a size fully equal to the largest of the elephants. Remains of *Dinotherium* have been found in the Miocene of India and Baluchistan and of central Africa, as well as in Europe and northern Africa, but its exact affinities and place of origin remain as yet unknown.

Trilophodon. The next stage in the ancestry of the mastodons and elephants is well shown in the fine *Trilophodon productus* skull. Although of a somewhat later age this species retains little changed the characters of the earliest known mastodons of the Lower Miocene of Europe, Asia and northern Africa. There is a very considerable gap between them and *Palæomastodon*, representing the evolution of the race during the whole of the Oligocene epoch. They are very much larger animals. The tusks are greatly lengthened, and rootless, growing from persistent pulps. The enamel is reduced to a rather narrow strip. The posterior grinding teeth are progressively enlarged, the anterior ones lost, falling out early in life. The cranium is built up into a great bulk by the cellular bony covering over the brain-case.

Tetralophodon, Dibelodon, etc. The numerous remains of mastodons in the Miocene and Pliocene of Europe, Asia and North America show a progressive divergence into several distinct types. In one series the elongation of the jaw, already great in *Palæomastodon*, is carried to an extreme, culminating in such types as *Tetralophodon campester* and *longirostris*. The intermediate molars have four crests, the last molar up to eight, but the cresting remains imperfect and the cross valleys are blocked. This is the *Tetralophodon* group of the late Miocene and early Pliocene of Europe, Asia and North America. In a second group, chiefly found in the New World, the upper tusks are enlarged and often curve upward; the band of enamel on their outer surface is sometimes retained but more often disappears completely. The lower tusks are lost, the jaw shortened, the posterior grinding teeth progressively enlarged, while the anterior ones are early lost. The teeth remain short-crowned although a small amount of cement is often present in the valleys. This is *Dibelodon*, common in the North American Pliocene and South American Pleistocene. All the Mastodons of South America belong in this group. In a third group *Rhyncotherium* the front of the lower jaw is bent downward at a sharp angle, the lower tusks large and straight. Little is known of this group, found only in Mexico and Texas.

Mastodon. A fourth group leads up into the great American Mastodon. In it the jaw is shortened, the lower tusks become vestigial, the cross crests of the molar teeth are perfected into a chopping tapir-like type. The upper tusks are large, curve upward with a spiral twist as in the elephants and have no enamel. Early stages are seen in *Trilophodon turicensis* of Europe, *T. brevidens* of Montana and *T. serridens* of Texas, of Miocene age; *M. borsoni* of the Pliocene and Pleistocene of Europe and *M. americanus* of the northern Pleistocene represent its culmination.

Stegodon, Elephas. The fifth and most important group leads up through the various species of *Stegodon* of the Pliocene of India into the elephants. In this group the jaw is greatly shortened, the lower tusks completely disappear and the upper tusks as in the American Mastodon are enlarged and curve upward. The posterior grinding teeth are progressively enlarged while the anterior ones are early lost. The crests of the molar crowns become progressively higher, narrower and more numerous, while the valleys are filled with cement, so that during wear the grinding surface presents cross ridges of enamel alternating with softer dentine and cement. The skull is greatly shortened, the trunk lengthened, the cranium built out with cellular bone, reaching finally the extreme specialization seen in the Pleistocene and modern elephants. The length of the limbs is also much increased, coördinately with the length of trunk.

The maximum of size is reached in the early Pleistocene elephants of Europe and North America—*E. antiquus*, *E. meridionalis*, *E. imperator*. But the mammoth shows the extreme of specialization in the grinding teeth, the enamel crests more numerous and closer set than any other species.

Origin and Dispersal of the Proboscidea. The fact that the oldest and most primitive remains of ancestral proboscideans have been found in Egypt has been commonly taken as proof that the original home of the order was in Africa. This may or may not be true. The absence of any ancestral proboscideans from the early Tertiary faunas of Europe and of the New World affords indeed reasonably conclusive evidence that they did not originate in those regions, and more indirect but fairly good evidence that they did not originate in the intervening regions of northern and central Asia from which a large part of their Tertiary faunas seems to have been derived. But of the early Tertiary faunas of southern Asia and of Africa we know nothing at all, save for the Fayûm faunas of northern Egypt, an area which is today transitional in its fauna between the two great regions, and decidedly more Asiatic than African in its affinities. While it is wholly probable that certain elements of the Fayûm fauna represent groups of early African origin, others are clearly of Asiatic affinities. It is not yet clear whether the Proboscidea are a group of Ethiopian or of Oriental origin. The choice is practically limited to these two regions.

The later evolution of the mastodons into the elephants appears to have taken place in the Oriental region, since intermediate stages are absent from the later Tertiary faunas of all the other regions, and a full series is found in India. But with the oncoming of the Glacial cold, the dispersal centre seems to have shifted to the north, for we find both in Europe and North America the highly specialized mammoth and mastodon spreading outwards from the north, and replacing other species more gigantic in size but less specialized in teeth. Today we find the African elephant, huge but somewhat primitive, surviving in a somewhat isolated tropical continent, and the Indian elephant, more progressive in its teeth but less so than the mammoth, surviving in tropical Asia, while the last step in specialization, the northern mammoth, after overrunning three continents in the later Pleistocene, has been completely swept away, following his predecessors in the northern countries to extinction. That the same fate awaits the African and Indian elephant, save as they may be preserved artificially in parks or by domestication, can hardly be doubted. Man has witnessed or aided in the extinction, during the short time that he has occupied the globe, of many magnificent types of the larger quadrupeds—but none so gigantic in size or so remarkable for peculiarities of structure and habits as are the great Proboscidea. That we have been able through the researches of science to preserve and reconstruct the

remains and restore the form and habitat not only of those extinct species known to our prehistoric ancestors, but of their ancestors and predecessors of older geologic epochs, and to trace the history and evolution of the race, may be some palliation for the widespread destruction and extinction of the greater quadrupeds that has accompanied the development of civilization.

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AMERICAN MUSEUM OF NATURAL HISTORY

DEALING WITH WATER SUPPLY,
DISPOSAL OF MUNICIPAL WASTES AND
INSECT-BORNE DISEASES

An Outline for Teachers and Students

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INTRODUCTION

The exhibits of the Department of Public Health were partly the result of the great anti-tuberculosis campaign of 1910, and partly the outcome of the work of the Metropolitan Sewerage Commission, which made it appear desirable to place before the public the sources of some wide spread diseases and the possibilities of their prevention. The subjects selected for exhibits were water supply and sewage, with their frequent relation to disease, and the more generally known diseases, such as malaria and yellow fever, due to or carried by insects. The exhibits were originally planned and arranged by Dr. C.-E. A. Winslow.

American Museum of Natural History

A BRIEF GUIDE TO THE PUBLIC HEALTH EXHIBITS

WATER SUPPLY

	(Notes Referring to Exhibits)
Most of the water on the earth's surface is stored in the oceans, from which it is drawn up or evaporated by the sun to form the clouds.	See 1st panel of painting, left wall.
The rain is the primary source of all water supplies. Rainfall varies considerably at different places.	WALL CASE 1 shows the number of rainy days at certain places and the actual rainfall in inches at others. DIAGRAMS presents graphically rainfall data for the whole United States.
Surface water flows off in rivers—which are swift at first, but slow and winding farther down.	See 3d panel of painting. See 4th panel of painting.
Slowly flowing rivers, unless contaminated by sewage from towns on their banks, are less apt to be dangerous than rapid ones, but safer than either are lakes in which the water is stored—undergoing through storage a natural purification.	See 2d panel of painting. Jars of rice in WALL CASE 2 indicate how typhoid bacilli die off during storage.
Another portion of the rain sinks at once into the ground, often to emerge at a lower level, forming a spring or well,—another common source of public water supply.	In an adjoining WALL CASE is a section of an artesian well.
Water may be hard or soft, turbid or clear, depending upon the amount and nature of the matter which it contains in solution or in suspension.	The physical character of five samples of water is indicated by blocks in WALL CASE 2.
Drinking water frequently contains microscopic organisms, most of which are harmless, although some of them produce tastes and odors in the water.	In WALL CASE 2 are also displayed enlarged glass models of micro-organisms (algæ, diatoms and protozoa) which occur in water. Their seasonal prevalance is shown by a CHART.

A common way of obtaining water supplies for large cities is by impounding streams in artificial lakes and reservoirs.

TABLE CASE A shows how a reservoir was formed near Boston, Massachusetts, for this purpose, and a large relief map shows the sources of the water supply of greater New York.

The increasing need of New York for water is illustrated by maps on the west wall which show the growth of the city up to 1845, three years after the introduction of Croton Water.

Occasionally disease-producing bacteria are present, derived either from direct sewage discharge or from the washing in of human wastes from the shore or through the ground.

In TABLE CASE C is an instance of an epidemic caused by disease-producing bacteria in drinking water.

Impure water must be either stored or treated before it is safe for drinking. Treatment may be by slow sand filtration, by rapid mechanical filtration after the addition of chemicals which produce a flocculent filtering layer, or by disinfection.

In FLOOR CASE 2 is a model of a mechanical filter and in FLOOR CASE 1 that of a slow sand filter and of an apparatus for disinfection with liquid chlorine.

A model of a plant for treating water with bleaching powder is exhibited in WALL CASE 2.

Purification of a water supply is usually followed by a marked drop in the typhoid fever death rate; from a purely economic standpoint this saving of life far outweighs the cost of treatment.

SEWAGE DISPOSAL

Cities usually discharge their sewage into the nearest large body of water: New York, for example, uses its two rivers and the bay for this purpose.

The sewage, sometimes washed back and forth for days by the tides, causes our waterways to be grossly polluted. Such a condition, always a menace to health, is especially dangerous in fresh-water streams or lakes where the polluted water has access to the supply of some other city.

CHARTS in FLOOR CASE 3 show the system of sewers in use by New York at present and the system as it will be when completed, the path of a float set adrift in the Hudson River, and the extent of pollution at various points. In the same case is depicted a scene on the water-front showing one dangerous phase of pollution.

The food supply may also become contaminated in this way.

Another model in FLOOR CASE 3 shows one way in which shellfish become polluted.

Such local nuisances and dangers to health may be avoided by treating sewage before it is finally discharged. To do this a city has several alternatives but the most effective process involves a number of successive treatments.

WALL CASE 3 contains a model of a plant for purification of sewage by the "trickling bed" method.

The coarse matter may first be removed by screening, after which the finer material may be allowed to settle as the sewage flows slowly through a sedimentation tank.

WALL CASE 4 contains models of a coarse bar screen, a revolving mechanical screen and a rotating Riensch-Wurl screen.
A sedimentation tank is also represented in WALL CASE 4.

Or sedimentation may be combined with digestion of the solids removed by the use of either a septic or an Imhoff tank.

Models of each of these will be found in WALL CASE 4.

The principle of both is the same, viz., that sludge, if allowed to accumulate under water, will be reduced in amount by the bacteria present in it. Imhoff tanks provide a separate lower chamber for this process.

The treatment may stop here or a final stage may be added, in which the organic matter in the sewage is oxidized and changed to a harmless mineral form.

This oxidization, which is brought about by bacteria, may be effected in either an intermittent sand filter, a contact bed of broken stone alternately filled with sewage and emptied, or a trickling filter—a bed of broken stone through which the sewage percolates after being sprayed over the surface.

WALL CASE 3 contains an intermittent sand filter in miniature.

Models of two contact beds are shown in WALL CASE 3.

In WALL CASE 3 is a model of a trickling filter in action.

In the so-called activated sludge process the oxidizing bacteria are culti-

vated in the sewage sludge itself and are supplied with compressed air from the bottom of the tank.

An activated sludge tank will be found in WALL CASE 3.

The country dweller may purify his sewage by installing a small septic tank and allowing its effluent to percolate through the sandy soil.

One possible arrangement is shown by a model in WALL CASE 4.

BACTERIA

Bacteria are minute single-celled plants. Most of them are harmless; some are necessary to the life and industrial pursuits of man; a few cause disease. When properly stained and viewed through a microscope, they are seen to occur in three shapes:

A WALL CASE contains enlarged glass models, showing how bacteria appear under the microscope, enlarged 25000 times; they represent the following types:

balls..... Staphylococci (2d panel).

rods..... Bacillus of tuberculosis (1st panel).

spirals..... Spirochæte of relapsing fever (bottom panel).

Different bacteria vary greatly in proportions and appearance. Some species have long, thread-like processes (flagella), which enable them to swim about, while others are surrounded with slime. A great many contain resistant spores and others contain granules, which give them a barred or spotted appearance.

See Bacilli in two central panels.

See acetic acid bacilli just above.

See one of the center panels. Bacillus of diphtheria (top row).

Bacteria may be made to live and multiply by planting them on a specially prepared jelly. Soon their numbers so increase that a colony of millions of microbes becomes visible at each point where a single germ was planted originally.

INSECT-BORNE DISEASES

An insect may carry disease from one man, or from one animal, to another in two ways:

1. By acquiring and then introducing the parasites during the act of biting:

A few of the most important diseases carried in this way are:

Sleeping Sickness—carried by the Tsetse fly.
Tick Fevers—carried by ticks.
Typhus Fever—carried by the body louse.
Yellow Fever—carried by the *Aēdes* mosquito.
Malaria—carried by *Anopheles* mosquitoes.
Bubonic Plague—carried by the rat flea.

With the exception of Bubonic Plague, these diseases can be contracted only through the agency of insects and in the way described above.

2. By spreading germs lodged on its body and feet.
   Typhoid fever organisms and germ of infant diarrhœa are sometimes carried in this way by the fly

SLEEPING SICKNESS

Sleeping sickness is a disease of man which has caused enormous fatality in Africa.

In WALL CASE 5 will be found a picture of a sufferer and near it a map showing the distribution of the disease.

Unfortunately the term has been applied to a very different disease that has had some prominence of late years in the United States.

It is produced by minute parasites called Trypanosomes, which live and multiply in the blood.

In WALL CASE 5 a photomicrograph of the organisms in the blood.

Various species of these parasites cause a number of tropical diseases of man and animals.

The organisms are spread by the biting tsetse-fly (*Glossina*) which inhabits dense wet places.

Specimens of the insect and pictures of its native haunts are in WALL CASE 5.

Sleeping sickness is sometimes treated by drugs.

A sample of Atoxyl (the drug used) is shown.

Our best means of fighting the disease is by controlling the insect-carrier.

The most effective control measures are:

1. Prevention of fly breeding by removal of sheltering bush.

A model in WALL CASE 5 helps to visualize this process.

2. Control of infected human beings and animals so that flies may not acquire infection. Inspection and quarantine will accomplish this.

Another model shows a quarantine camp.

3. Protection of healthy persons against fly bites. Proper clothing and screening and avoidance of dangerous localities are the means.

Marked success has attended the fight against the tsetse-fly.

TYPHUS FEVER AND OTHER INSECT-BORNE DISEASES

There are a number of diseases which depend for their existence upon insect-carriers. A few of these are treated in the Public Health exhibits.

Diseases of Man: Typhus fever is a disease which was once very prevalent in army camps. It is caused by a parasite which is transmitted by the bite of the body louse.

A large wax model of the body louse will be found in FLOOR CASE 7.

Modern sanitary methods have brought it largely under control.

The upper shelf of WALL CASE 5 is devoted to typhus control, and a chart in the center indicates the effectiveness of the campaign.

Relapsing fever is a tropical disease carried by ticks and caused by a blood parasite (*Spirochæta*).

Owing to social conditions in the tropics, control is difficult, and the method most often employed is the destruction of the infected dwellings.

A model at the right of the bottom in WALL CASE 5 depicts such a scene.

Elephantiasis is another tropical disease caused by a relatively large, worm-like parasite called *Filaria*. This animal obstructs the blood vessels, causing an enlargement of some extremity.

See Photomicrograph in WALL CASE.

In WALL CASE 5 is a picture of a person so afflicted.

Mosquitoes of the genus *Culex* carry the young parasites from diseased to healthy persons.

Chagas fever is a disease of children in Brazil, which is carried by the bites of certain bugs.

Specimens of these bugs are shown in WALL CASE 5.

Diseases of Cattle: Cattle are frequently sufferers from the ravages of blood parasites of which little is known save that ticks are the sole carriers.

In WALL CASE 5 are specimens of the principal offending ticks and a piece of cowhide which tells the story of the creature's abundance.

The diseases are very serious in some parts of the United States and are responsible for great financial loss to the country.

In WALL CASE 5 is a picture of Bitter Root Valley, where a human tick-borne disease, Rocky Mountain Spotted Fever, has prevailed.

The most effective means of control is the frequent treatment of cattle with poisonous washes. Arsenic solutions—the poison most used—may be applied by immersion or by spraying.

The right of the middle shelf of WALL CASE 5 is devoted to the various devices used by cattle raisers for the protection of their stock

MALARIA

Malaria is an important disease responsible for an annual loss of $100,000,000 in the United States.

The distribution of Yellow Fever and Malaria, and of the Mosquitoes through which these diseases are transmitted are shown on a map over TABLE CASE C.

It is caused by a protozoan parasite (*Plasmodium*), living part of its life in the blood of human beings, and part in the body of the *Anopheles* mosquito.

A chart in the top of WALL CASE 6 gives the points of difference between the malaria carrier and the common mosquito. The geographic distribution of the disease and that of its carrier are mapped in a CHART.

Mosquitoes of this kind become infected by biting a malaria sufferer and spread the disease by subsequently biting healthy persons.

To wipe out malaria we must cure cases by quinine treatment and exterminate the insect-carrier.

A model on the middle shelf illustrates the use of quinine in Panama, and a chart near by indicates the reduction of malaria in Italy due to the use of quinine dispensed by the Government.

To fight an enemy successfully, its habits must be known. Those of the mosquito are well understood.

A series of three jars giving the life cycle of the mosquito (left) and a set of collecting implements used in studying its natural history are also shown in WALL CASE 6.

Water is essential to mosquito breeding, for on its surface the eggs are laid and in it the early stages must live.

A chart in WALL CASE 6 pictures a breeding place on the shore of the Nile.

In warm weather mosquitoes reproduce most rapidly.

Relief maps in TABLE CASES D and E indicate the prevalence of malaria near marshlands.
A chart in the upper left corner of WALL CASE 6 gives data to illustrate this fact.

Our safety from malaria depends on the following mosquito-control measures:

1. Prevention of mosquito breeding—

   Swamps should be drained by ditching.

In TABLE CASE D is a relief map showing a well drained marsh and in WALL CASE 7 is a model of a concrete ditch such as was used at Panama.

   Overhanging grass should be cut from the edges of all ditches, streams and pools.

In the bottom of WALL CASE 6 is a group showing how this is done in Panama.

FLOOR CASE 4 shows the difference between a well kept farm, properly drained, and one where conditions are unsanitary.

   Cast-out pots and cans should be removed to prevent the accumulation of rain-water, while for rain-barrels, screening is essential.

A typical vacant lot breeding-place is reproduced in the bottom of WALL CASE 6 and above is a properly screened rain-barrel.

2. Destruction of wigglers—

   They may be suffocated by oiling the surface of the water in which they live, or killed by poisoning.

Samples of oil are arranged on the middle shelf of WALL CASE 6, and a jar just above shows the condition produced by oiling. At the lower left corner of the case is a barrel used for applying oil to running water. The picture above it is of an oiling squad in New Jersey.

A sample of the poison used in Panama is shown.

   Their natural enemies, especially small fishes, should be encouraged.

The most important insect enemies of the mosquito are displayed in WALL CASE 6 also a group of fishes devouring their prey.

3. Destruction of adult mosquitoes by fumigating—

   Cellars in which they hibernate and houses in which cases of malaria have occurred should receive special attention.

4. Screening to keep mosquitoes away from malaria patients from whom infection may be derived and away from healthy persons whom they might infect.

In WALL CASE 7 is shown a screened hospital compartment, and a portable net for protection against mosquitoes.

When the use of screens is impracticable it is often possible to drive mosquitoes away by the use of repellants.

Samples of repellants are shown in WALL CASE 6.

The phenomenal success of the battle against mosquito-borne disease is discussed in the section on yellow fever.

YELLOW FEVER

To the right of WALL CASE 8 are portraits of the heroes who decisively proved that Yellow Fever was transmitted by a mosquito, also portraits of General Gorgas who directed the campaign against the Yellow Fever Mosquito, and of Howard Taylor Ricketts who discovered the source of Texas Fever.

Yellow fever is a tropical disease, the cause of which was shrouded in mystery until the beginning of this century, when its connection with the mosquito was established.

The germ remains as yet undiscovered, but it is known to be carried by the *Aēdes* mosquito just as the malaria parasite is carried by the *Anopheles*

An enlarged model of *Aēdes* will be found in FLOOR CASE 7.

Aēdes, being an inhabitant of houses, breeds more often in vessels of stagnant water than in swamps and streams. It is fought by practically the same measures as *Anopheles*, though fumigation is more important than in the case of the malaria carrier. It is the common practice in Panama to fumigate an entire house in which a case of yellow fever has occurred.

Such a scene is shown in WALL CASE 7.

The wonderful success of the battle against mosquito-borne disease is nowhere better illustrated than in the history of the Panama Canal.

Our country was not the first to attempt this enterprise but it was the first to cope with the mosquitc, and hence to succeed in building the canal.

IN WALL CASE 7 are shown a French and an American hospital at Panama. The difference explains why France failed and America built the Canal.

Without the sanitarian, the engineer was helpless; with him the greatest engineering feat in history was accomplished.

Many other plague spots have been cleaned up by the same means, and other projects than the great Canal have been made possible by war on the deadly mosquito.

CHART 22 and a chart in the bottom of WALL CASE 7 give the results of sanitary work in Havana.

BUBONIC PLAGUE

Since the sixth century, Bubonic Plague has swept three times over the world, killing millions of people.

A CHART between CASES 8 and 9 gives the range of each pandemic.

Copies of old paintings, show how the scourge impressed the ancients. An enlarged glass model of the germ (*Bacillus pestis*)) will be found in WALL CASE 8, and in the same case are displayed four species of rats most often concerned. FLOOR CASE 5 contains a model of part of an actual house, which was badly infested with rats.

It is a bacterial disease,

primarily of the rat,

spread and carried to man by the bites of infected fleas.

An accurate model of the Rat Flea magnified one hundred and twenty times, is installed in FLOOR CASE 7.

In California two species of squirrels are subject to the disease,

while in Asia the marmot must be reckoned with. To control the plague we must fight the rat and the other rodents mentioned.

Mounted specimens are in WALL CASE 8, and in FLOOR CASE 6 the most important species is shown in its natural surroundings.

The most effective measures are:

1. Prevention of rat breeding—Clean up rubbish and cut off the rats' food supply.
2. Destruction of rats—Poison or trap them and fumigate enclosed spaces.
3. Exclusion of rats from dwellings by rat-proofing.
4. Quarantine against vessels from infected regions by placing rat guards on the hawsers, etc.

In WALL CASE 8 are three good traps and beside them is a model showing the results from their use.

On the shelf is a model of a farm protected against rats

and one of a schooner with rat guards in position.

Plague, under certain conditions, may also be spread by the mouth spray from a coughing patient.

A fair degree of immunity may be produced for a short time by the use of vaccine.

On a shelf of WALL CASE 8 are shown the costume and respirator worn to protect against this danger.

Samples of the commercial product are just beneath.

THE FLY

A great many species of flies are found in houses, but the preponderant type is the well-known House Fly (*Musca domestica*). This insect is our commonest and most dangerous household pest.

Between WALL CASES 8 and 9 are enlarged drawings of our more common species of flies.

During its life the fly passes through four stages: egg, larva, pupa and adult.

In FLOOR CASE 7 is a huge model of the House Fly, adult and earlier stages.

In WALL CASE 9 a series of four jars illustrates the fly's life cycle, while charts give the time required at various temperatures for the complete transformation and the relative importance of various breeding substances. A jar on the bottom shelf shows the number of flies found breeding in a pound of manure.

The eggs are laid by the female in filth of some sort—preferably in horse manure, but frequently in human excreta.

The larva or maggot, hatching from the egg, feeds upon this substance and grows to a length of perhaps half an inch, when it burrows down to a dry place and, upon casting its skin, becomes a dormant pupa. From this pupa the adult fly emerges, to wing its way from filth to our food.

As each female lays an average of one hundred and twenty eggs, and as nine generations are possible in one season, a single female may, under ideal conditions, be responsible for several hundred trillion offspring.

This fact is illustrated by four jars and a picture on the top shelf of WALL CASE 9.

As a result of its nasty habits, the fly is a germ-laden creature.

Several culture plates in the same case show the bacteria which developed in the tracks of a fly, and tubes of sand represent the number of bacteria washed from flies.

If it has access to human discharges and then to food the fly may become a disease bearer. The fly was largely responsible for typhoid fever during the Spanish-American War, while it has been suspected of causing epidemics in times of peace. It has been shown that infants in fly-infested houses of New York City are visited by two and a half times as much summer complaint as those in clean homes.

See a model in WALL CASE 9 and a small map.

A model in the center of the same case illustrates this fact.

Such conditions as these demonstrate the necessity of ridding ourselves of the fly. This is best done by the following means:

1. Prevention of fly breeding:
   All manure should be either covered or disinfected.
   Exposed refuse should be cleaned up. Maggots may be destroyed in a maggot trap. The fly's natural enemies should be encouraged.

A covered manure bin and sample of borax and hellebore for disinfecting manure are shown.

One such trap is exhibited.

The most important fly enemies are grouped in WALL CASE 10.

2. Destruction of adult flies:
   They should be trapped or killed with fly-paper, fly-poison and the swatter.

A good fly-trap is shown in WALL CASE 9.

3. Guarding human excreta against access of flies:

Flies cannot carry typhoid from a properly screened and enclosed privy.

and on the shelf above are two types of safe privies explained by models.

4. Keeping flies out of houses and away from food:
   A screened window in summer may be valuable health insurance. The storekeeper who does not protect his foods from flies is your enemy.

Facts and figures have shown that war on the fly is worth while.

Drawings to the right of WALL CASE 10 illustrate methods of protection against the Tsetse Fly Rat Flea, Mosquito and Fly.

Military Hygiene

One of the great problems in the past was keeping soldiers in good health. So late as the Spanish War (1898) more soldiers were killed by disease than by bullets, one of the most deadly diseases being typhoid fever.

See WALL CASE 11 for illustration.

A large proportion of the tyhpoid cases was due to infection through the agency of flies mainly due to improper latrines.

See WALL CASE 9 for danger from flies.

See WALL CASE 11 for proper treatment of waste .

Another safeguard against typhoid is inoculation.

See WALL CASE 11.

THE HOUSE FLY OR TYPHOID FLY

One of the Exhibits in the Hall of Public Health

Reference

THE BOUND TO PLEASE
Heckman Bindery INC.
APR. 65
N. MANCHESTER, INDIANA

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